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ENVIRONMENTAL CONDITIONS IN THE NORWEGIAN-ICELAND SEAS

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MAY 1987(U) NAVAL OCEAN RESEARCH AND DEVELOPMENT

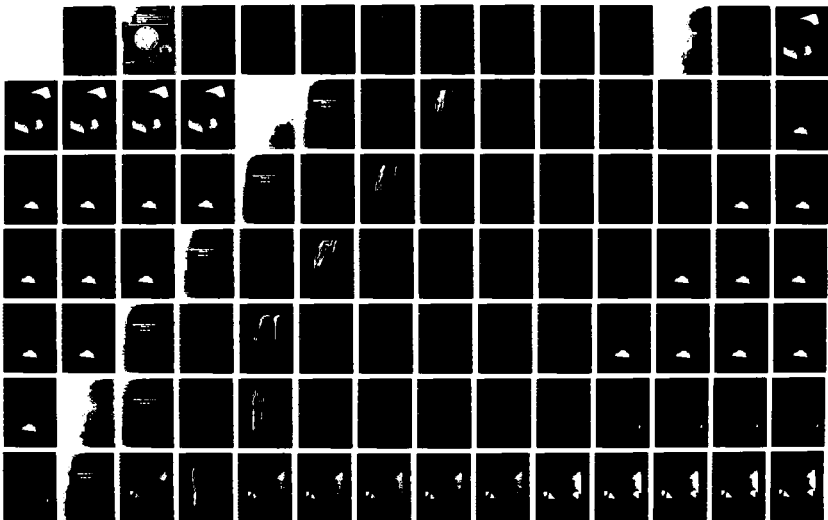
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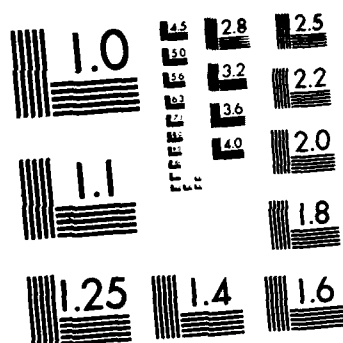
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**Preliminary Report:
Environmental Conditions in the
Norwegian-Iceland Seas,
May 1987**

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June 1987

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PRELIMINARY REPORT: ENVIRONMENTAL CONDITIONS IN THE NORWEGIAN-ICELAND SEAS, MAY 1987

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ABSTRACT

(U) In support of the Tactical Oceanography Prediction Experiment an extensive series of thermal structure measurements have been made in the Iceland and Greenland Seas with emphasis on the Iceland-Faeroe frontal region. A preliminary analysis of these measurements is given.

INTRODUCTION

(U) This preliminary report describes field work carried out by NORDA personnel and NORDA sponsored personnel during the period 15-30 May 1987. This is the initial phase of a continuing series of field experiments in the Greenland, Iceland, and Norwegian seas in support of the National Maritime Strategy. The field work was divided into four segments: (1) aircraft observations using air deployed expendable bathythermographs (AXBTs) dropped from a Naval Research Laboratory (NRL) P-3; (2) near-real-time tactical scale thermal analyses and oceanographic predictions by NORDA at the Anti-Submarine Warfare Operations Center (ASWOC), Keflavik, Iceland; (3) near-real-time tactical scale ocean dynamic forecasts at the Naval Oceanography Command Facility (NOCF), Keflavik, Iceland, by the Harvard team (Alan Robinson, Donald Denbo, Scott Glenn, Michael Spall, and Leonard Walstad) using an open ocean model; and (4) ship observations aboard the West German ship PLANET. This report concentrates on the first two segments by briefly describing the field efforts and the analysis/forecast segment of the operation. Some initial findings concerning the environmental conditions in the Norwegian-Iceland Seas during May 1987 with figures detailing these conditions conclude the report. In-depth summaries of the results will follow in later publications.

TACTICAL OCEANOGRAPHY PREDICTION EXPERIMENT

(U) One of NORDA's major long range goals is the development, validation and delivery for operational use of oceanic and acoustic numerical forecast systems, and the assimilation of in-situ and remotely sensed data into these forecast systems. The Tactical Oceanography Prediction Experiment, a key element of this goal, is designed to provide the exploratory development for the future integration of ocean measurements, dynamic and thermodynamic numerical ocean models, and range dependent numerical acoustic performance prediction models into an end-to-end prediction system running on the Standard Navy Desktop Computer.

(U) The Tactical Oceanography Prediction Experiment can be viewed as a set of four tasks:

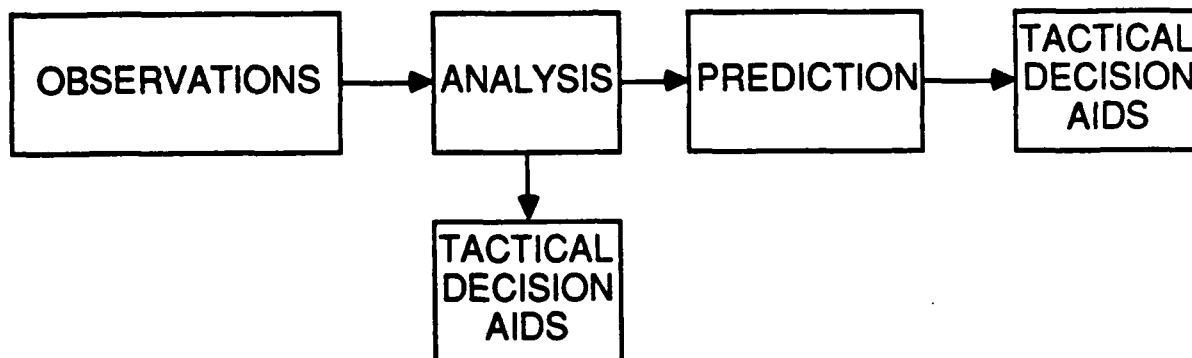


Figure 1. Tactical Oceanography Prediction Experiment.

(U) **OBSERVATIONS.** The observational component had five goals: (1) to provide near-real-time initialization and validation fields of the Iceland-Faeroe Front, via NORDA's desktop version of the Optimal Thermal Interpolation System (OTIS), for NORDA's desktop computer version of the Thermodynamic Ocean Prediction System (TOPS); (2) to provide near-real-time initialization and validation fields of the Iceland-Faeroe Front for the Harvard open boundary ocean dynamic prediction model; (3) to provide initialization fields for the NORDA ocean circulation model of the Greenland-Iceland-Norwegian Seas; (4) to provide near-real-time analyzed and predicted sound speed fields for range dependent acoustic predictions on tactical scales; (5) to contribute to an improved understanding of the regional hydrography, circulation, and frontal structure of the region. These goals were viewed as ambitious but achievable within the context of several experimental phases. All goals were met to a greater or lesser extent during this first experiment, although considerable improvement of technique still remains to be accomplished.

(U) **ANALYSIS.** The goal of the thermal analysis task was primarily to produce near-real time objective maps of the ocean thermal structure on a local microcomputer. These uniform fields were to be available for (1) displays to aid further data gathering efforts, (2) boundary and initial conditions for numerical models, and (3) environmental fields for input to the range-dependent acoustic models. The figures shown in this report are representative of the output generated by this task.

(U) **PREDICTION.** The goal of the prediction element was threefold: (1) using TOPS together with the winds forecasted by the Navy Operational Global Atmospheric Prediction System (NOGAPS) predict in near-real time the thermal structure of the Iceland-Faeroe front for upto 72 hours; (2) using the Harvard open ocean model (GAPCAST) predict in near-real time the currents in the frontal region for upto a week; (3) using a range dependent acoustic model predict the acoustic propagation across the front.

(U) **TACTICAL DECISION AIDS.** The goal of this element is the development of graphical representation of the information from the analysis and prediction elements for the tactical decision maker to aid in resource allocation.

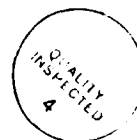
DATA COLLECTION AND ANALYSIS

(U) Eight research flights were conducted by NORDA personnel on board a Naval Research Laboratory P-3 aircraft operating out of Keflavik, Iceland between 15 and 30 May 1987. Four hundred twenty shallow (nominally 305 m) and fifty deep (nominally 750 m) AXBTs were successfully deployed and analyzed. The dates and regions of operations were:

| Flight | Date | Region |
|--------|-------------|------------------------|
| 1 | 15 May 1987 | Iceland-Faeroe Front |
| 2 | 18 May 1987 | Iceland-Faeroe Front |
| 3 | 20 May 1987 | Jan Mayen Front |
| 4 | 22 May 1987 | Iceland-Faeroe Front |
| 5 | 24 May 1987 | Iceland Sea |
| 6 | 26 May 1987 | Iceland-Faeroe Front |
| 7 | 28 May 1987 | Southern Norwegian Sea |
| 8 | 30 May 1987 | Northern Norwegian Sea |

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These regions are shown schematically in Figure 2.



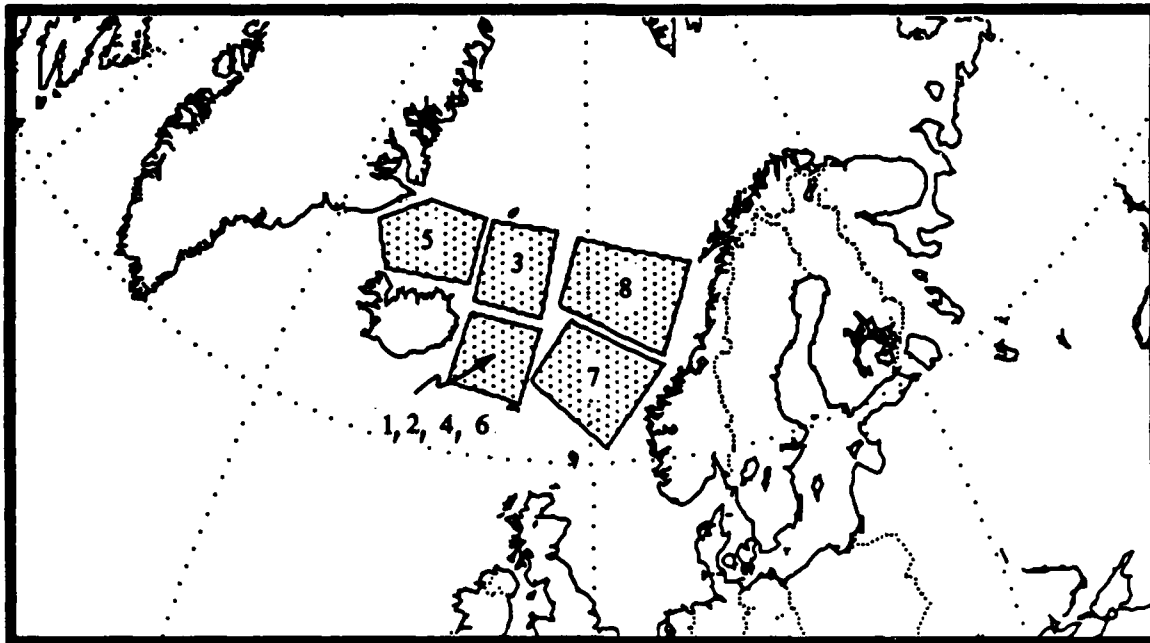


Figure 2. Aircraft measurement areas.

(U) The data were collected using two micro-computer based data acquisition systems, plotted in near real-time, and had major inflection points digitized by hand (flights 1-4) or with a digitizing tablet (flights 5-8) immediately after conclusion of each flight. (The initial data acquisition system had to be replaced by the second due to a computer failure.) Navigation information was merged with the profiles, and the data was checked against climatology to eliminate bad traces that were not apparent to the eye. The edited data was then both passed to the Harvard team for their use and analyzed by the NORDA TTAP (Tactical Thermal Analysis Package) thermal analysis system. All data was digitized and analyzed within 24 hours of conclusion of a flight.

(U) The NORDA Tactical Thermal Analysis Package (TTAP) is a FORTRAN coded software package that allows the user to manipulate the AXBT data in various ways. It includes provisions for plotting the data values at arbitrary depths on a map of the experimental area as well as plotting station designators and individual or overlayed temperature vs. depth plots. Most importantly, it provides a method for producing uniformly gridded fields from the somewhat randomly spaced experimental measurements. These meshed fields can be arranged on horizontal planes as temperature contours at a given depth, or on vertical planes as vertical temperature cross-sections. These programs were designed to operate on a microcomputer capabilities that approximate that of an IBM-PC/AT

(U) The method used to obtain the temperature estimates at the grid nodes of the user-defined mesh is that of optimal estimation (statistical interpolation). This method bases its estimates on the spatial and temporal covariance functions of the field of interest (Gandin, 1963). For this analysis

a simple exponential representation of the covariance function was chosen. The scale of the exponential decay (e-folding distance) is chosen to fit the sampling scheme and the scales of interest in the temperature field. For the Iceland-Norwegian Sea experiment the horizontal scale was chosen to be 50 km. Temporal and vertical correlations were not considered for this experiment. The analyses shown in this report use a grid spacing of about 10 km. The initialization or "first guess" field used was the Global Digital Environmental Model (GDEM), which is defined on a 0.5 degree grid, interpolated to the grid of interest. Although they were originally performed on a Zenith Z-248 operating on site at the ASWOC in Keflavik, Iceland, the calculations were repeated at a higher resolution on a VAX 8800 for this report.

ENVIRONMENTAL CONDITIONS, MAY 1987

(U) The NORDA thermal analysis system (TTAP) was used to produce the following figures. They fall into four appendices: (A) analyses of the full 15-day dataset covering the Iceland and Norwegian Seas; (B) analyses of the four intensive surveys of the Iceland-Faeroe Frontal Zone; (C) analyses of the Jan Mayen Frontal Zone, Iceland Sea, and southern and northern Norwegian Sea surveys; and (D) temperature versus depth cross-sections along selected transects through the major frontal regions.

Appendix (A) Norwegian-Iceland Sea

(U) The first few figures show the near-synoptic composite picture given by combining all eight Norwegian-Iceland Seas operations. The flights covered the region with 20-60 nmi resolution between about 61°N - 70°N and were designed to provide an initialization field for the NORDA regional ocean circulation model of the area as well as to advance the understanding of the regional hydrography, circulation, and frontal structure.

(U) The major frontal features of the area are quite clear in the temperature contours at 0, 100, 200, 300, and 400 m: the Kolbeinsey Current Front north of Iceland, the Iceland-Faeroe Front between Iceland and the Faeroe Islands, the Jan Mayen Front north of 65° N and between 5-10° W, and the Norwegian Current Front between about 0-6° E. All the frontal positions lie close to their 1980-81 locations as described by Smart (1984). No sign of the East Greenland Front paralleling the eastern Greenland coast can be seen, although visual observations were made from the aircraft during the Iceland Sea survey (24 May) of an ice-free region all along the Greenland coast and extending offshore 10-20 miles which conceivably could have been the East Greenland Current flowing very close to the coast.

Appendix (B) Iceland-Faeroe Frontal Zone Intensive Studies

(U) The four intensive (20-30 nmi spacing) surveys of the Iceland-Faeroe Frontal Zone were designed to provide initialization and validation data for mixed layer and local scale circulation modelling. From these surveys considerable information can be gained about the temporal and spatial structure of the front. Each series of figures in this section consists of: (a) successful AXBT drop locations and corresponding station numbers; (b) a composite temperature versus depth plot of all traces; (c) drop locations and corresponding temperature values at 0, 100, 200, 300, and 400 m; (d) horizontal contours of the temperature data in (c).

(U) The composite temperature versus depth plots are distinctly bimodal, with the colder near-surface profiles representing water of Arctic origin, while the warmer near-surface profiles are from water of Atlantic origin. The development of a mixed layer over the intervening 11 days, especially in the Atlantic water, is evident in the later surveys.

(U) The Iceland-Faeroe Front is well resolved at all depths and located in the southern portion of the range suggested by Smart (1984). The frontal slopes down to the south, although it is more clearly seen in the vertical transects in Appendix (D). A noteworthy feature is the northward bulge of the front between about 10-12° W which persisted throughout the surveys, although its shape and depth of penetration varied. A very distinct warming trend penetrating all the way to 400 m appeared by the fourth survey on 26 May.

Appendix (C) Jan Mayen Front, Iceland Sea, and Southern and Northern Norwegian Sea Studies

(U) The Jan Mayen frontal zone lies between the Iceland and Norwegian Seas. This is clearly seen in the bimodal structure of the composite temperature versus depth plot for the 20 May survey. One group of profiles with near-surface values between 0 and 2.5° C corresponds to Iceland Sea waters which have been formed in the region, while the other group (near-surface temperatures of about 3.5 to 6° C) represents Norwegian Sea waters of Atlantic water origin. The Jan Mayen Front itself is clearly seen in the subsequent plots as a distinct but rather diffuse front centered around 7° W. The cross-frontal temperature change was around 3° C, and the front was visible to at least 400 m. It extended primarily north-south, with a distinct westward bulge in its most intense region between 68 and 69° N.

(U) The Iceland Sea operations on 24 May were conducted over extensive areas of 40-70% ice cover except relatively close to Iceland and within a few tens of miles of the Greenland coast. Much of the ice was presumably fairly thin, since east of about 22° W the AXBT success rate was only somewhat degraded. West of 22° W the character of the ice changed into much larger agglomerations while the probe success rate plummeted to nearly 0, and the flight was terminated early.

(U) The composite temperature versus depth plot for this survey shows four different profile regimes. The first, with near-surface values of about -1.5 to -1° C, occurred in the northwestern portion of the area and represented Polar water originating in the Arctic and brought into the region by the East Greenland Current. The second group of profiles (near-surface temperatures in the -0.5 to 0.5° range) lay predominately to the northeast and consisted of the locally formed Iceland Sea water. The third group, rather broadly distributed between 1 to 2.5° C, probably consisted of waters formed from the mixing of one or both of the first two types with the fourth. This fourth group, with near-surface temperatures of 3.5 to 6° C, was water of Atlantic origin, part of the current flowing around Iceland and passing eastward along the island's northern coast, which is known variously as the Kolbeinsey Current, the East Icelandic Current, or the Iceland Current.

(U) The frontal zone between the Kolbeinsey Current water and the Polar and Arctic waters to the north is very apparent in the subsequent plots in this section. As also noted by Smart (1984), the front slopes downward to the south, reflecting topographic influences. Its near-surface manifestation bows outward to the north, while at depth it more closely parallels the Icelandic coastline.

(U) Figures for the southern and northern Norwegian Sea surveys are grouped somewhat

differently from the other surveys. We first present the drop locations, composite temperature versus depth plots, and drop locations with corresponding temperatures at 0, 100, 200, 300, and 400 m for the individual surveys. Following these figures are the temperature contours at the four depth levels for both surveys combined.

(U) The composite temperature versus depth plots are unimodal. The near-surface temperatures range between 4.5-9.5° C, and represent Norwegian Atlantic Current water of North Atlantic origin and mixtures of this water with Norwegian Sea water. Considerable structure and temperature inversions characteristic of frontal regimes can be seen in some of the profiles, particularly in those from the southern Norwegian Sea survey.

(U) The Norwegian Current Front is apparent in the western half of the temperature contour plots at 0, 100, 200, 300, and 400 m. It is more easily seen at 100 m and below than at the surface, and north of 65-67° N bends westward and becomes considerably more poorly defined. A downward slope of the front to the east toward Norway reflects topographic effects.

Appendix (D) Temperature versus depth transects

(U) Three temperature versus depth transects were drawn through the major frontal zones in the Norwegian-Iceland Seas: (1) from 12° W, 63° N to 8° W, 66° N through the Iceland-Faeroe Front; (2) from 14° W, 69° N to 6° E, 66° N through the Jan Mayen and Norwegian Current Fronts; and (3) from 18° W, 66.5° N to 20° W, 70° N through the Kolbeinsey Current Front. A brief discussion of some of the major features of each transect follows.

(U) The first set of transects is for the four intensive Iceland-Faeroe Frontal Zone surveys. The front was very well resolved on all four surveys. On 15 May it was nearly vertical, but by 18 May the upper 50 m appeared to have been moved northeastward by 50 km or so and the surface definition spread out, presumably by advective effects. On 22 May the whole frontal signature was less intense at all depths, and a distinct frontal slope downward to the south of about 200 m in 100 km can be seen. Four days later, on 26 May, the southern 100 km of the area became noticeably warmer, with the warming trend becoming particularly noticeable and penetrating farther north in the upper 50 m or so. The intensity of the front also increased.

(U) A final comment concerns the location of the deep portion of the front, which might be expected to be more stable than the surface portion because of the influence of bathymetry on its location. This may be true for the front as a whole, but the deep position of the front along our selected transect seemed to vary significantly on time scales of only a few days during May 1987. On 15 May the front at 400 m was located between approximately kilometers 95 and 170 along the transect. A portion of the front remained in this general vicinity during subsequent surveys, but beginning on 22 May another part of the front seemed to form between kilometers 0 and 50 along the transect and became its more significant manifestation.

(U) While the Jan Mayen front and the gradient associated with the Norwegian Current are clearly visible in the transect across the northern Norwegian Sea, these fronts are not nearly as intense as that along the Iceland-Faeroe ridge. As a comparison both the Jan Mayen and Norwegian current temperature gradients are about 1 C in 60 km whereas the Iceland-Faeroe gradient is as high as 1° C in 10 km. The Jan Mayen front (about 300-400 km range in the figure) is quit vertical in this realization except perhaps near the surface. The Norwegian current (at about 700 km range in the figure) is also well defined but with not nearly such vertical isotherms. An intrusion of warm surface water (> 8° C) is a prominent feature which defines the surface

expression of the Norwegian current.

(U) The Kolbeinsey Current Front is clearly visible in the south-to-north transect which concludes the figures. The water to the north of this front is a nearly homogenous 0°C representing cold Iceland Sea water. Judged by some historical references the frontal position is rather far offshore--the warmer ($3-4^{\circ}\text{C}$) water of the costal Iceland current occupying the nearest 150 km along the Icelandic coast. One interesting feature of the transect is the reverse slope of the surface isotherms near the 180 km range.

ACKNOWLEDGEMENTS

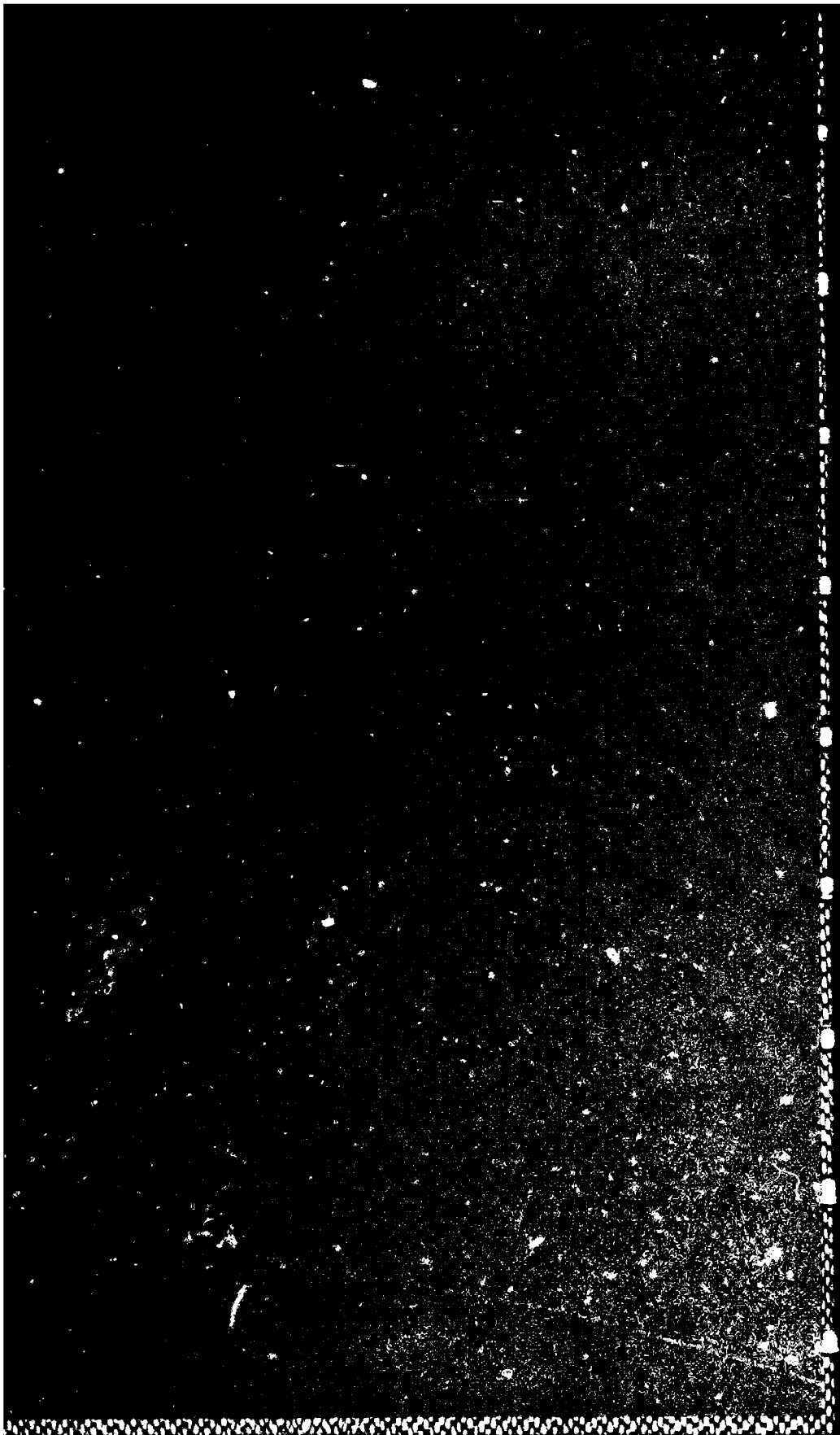
(U) The efforts and cooperative spirit of LCDR Jim Jarvis and the other officers and crew of the Naval Research Laboratory P-3A #150607 are gratefully acknowledged. Glen McCardle of the NORDA Ocean Technology Division ably operated the data acquisition systems on board the aircraft and successfully tackled the many problems that arose. Heartfelt thanks are due to Ron Miles and Robert Brown, also of the NORDA Ocean Technology Division, without whose long-distance problem solving skills the operations would not have succeeded. At the Naval Air Station, in Keflavik, Iceland we could not have operated without the help of individuals from the Naval Oceanography Command Facility and the Anti-Submarine Warfare Operations Center. Particular thanks should be given to CDR R. T. Pearson, LT K. A. Wos, LT M. B. Clifford, and CDR R. C. McIntosh.

(U) These efforts were sponsored principally by the Office of Naval Technology through the Tactical Oceanography Project (62435N) with additional support from the Office of Naval Research through the Space Oceanography Project (61153N) and from the Space and Naval Warfare Systems Command through the Air-Ocean Prediction Project (63297N).

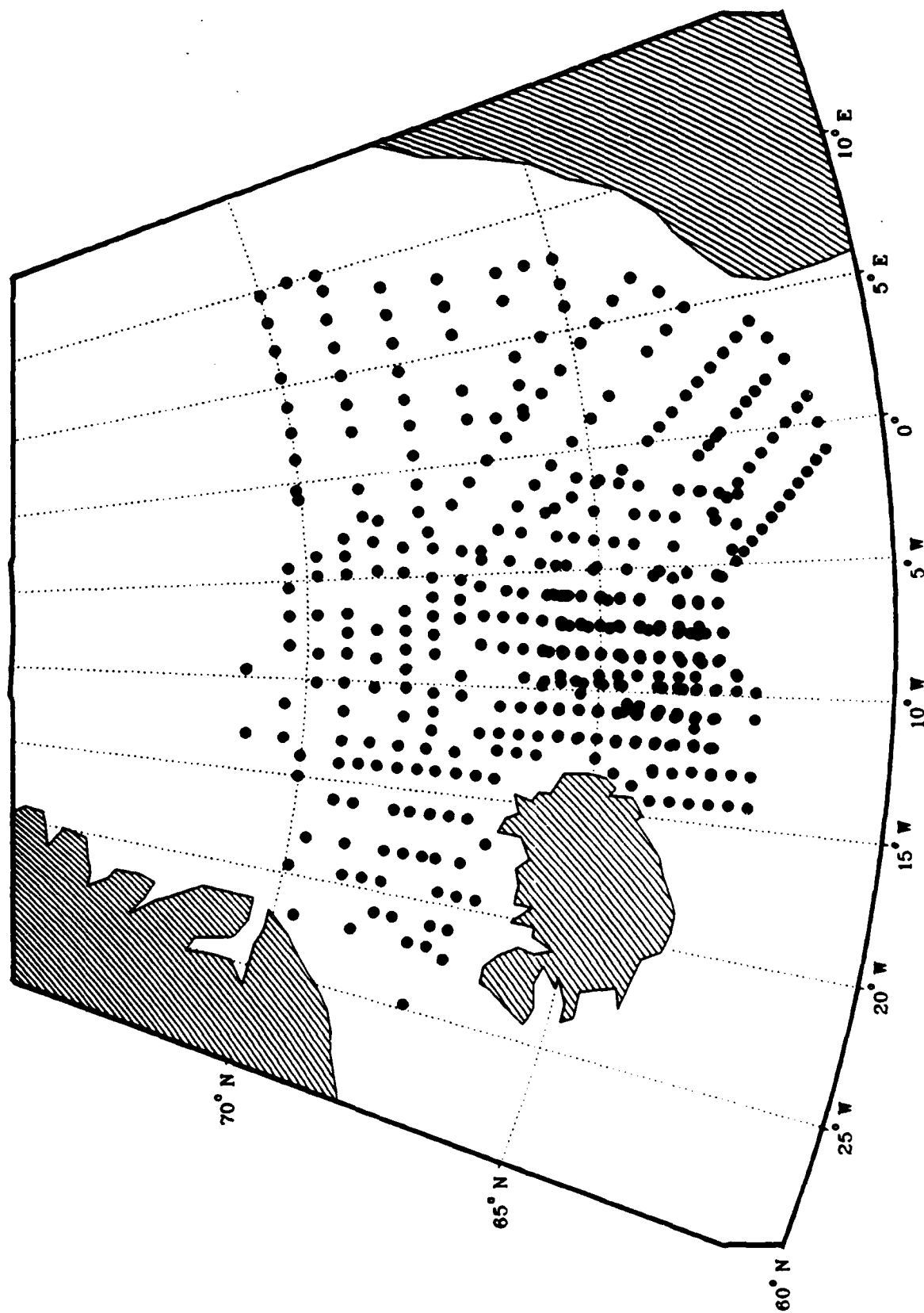
REFERENCES

Smart, J.H. 1984. Spatial variability of major frontal systems in the North Atlantic-Norwegian Sea area: 1980-81. *Journal of Physical Oceanography*, 14, 185-192.

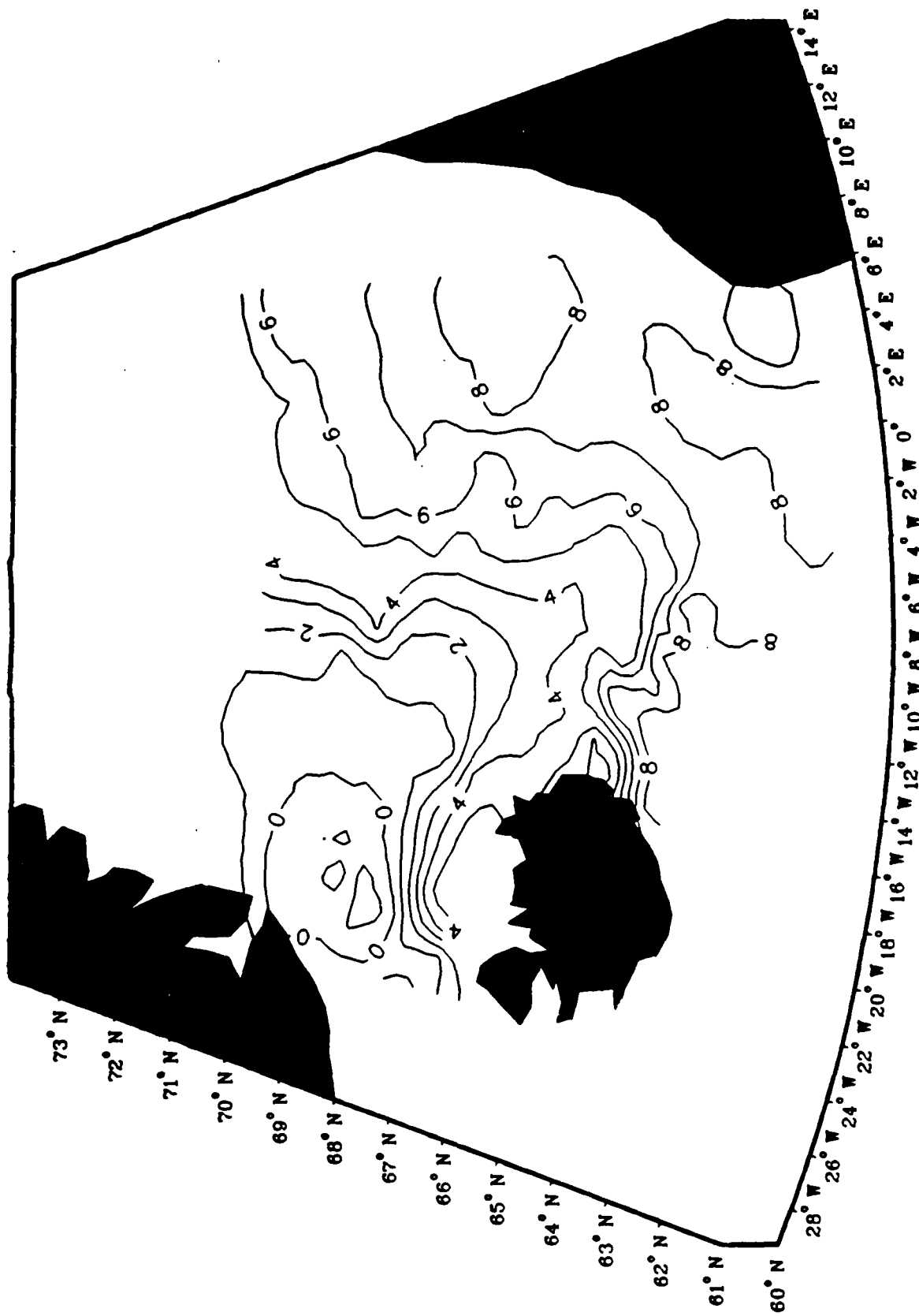
Gandin, L.S. 1963. *Objective Analysis of Meteorological Fields*. Leningrad, Gidromet. (Jerusalem, Israel Program for Scientific Translations, 1965. 242pp. available as NTIS TT65-50007)



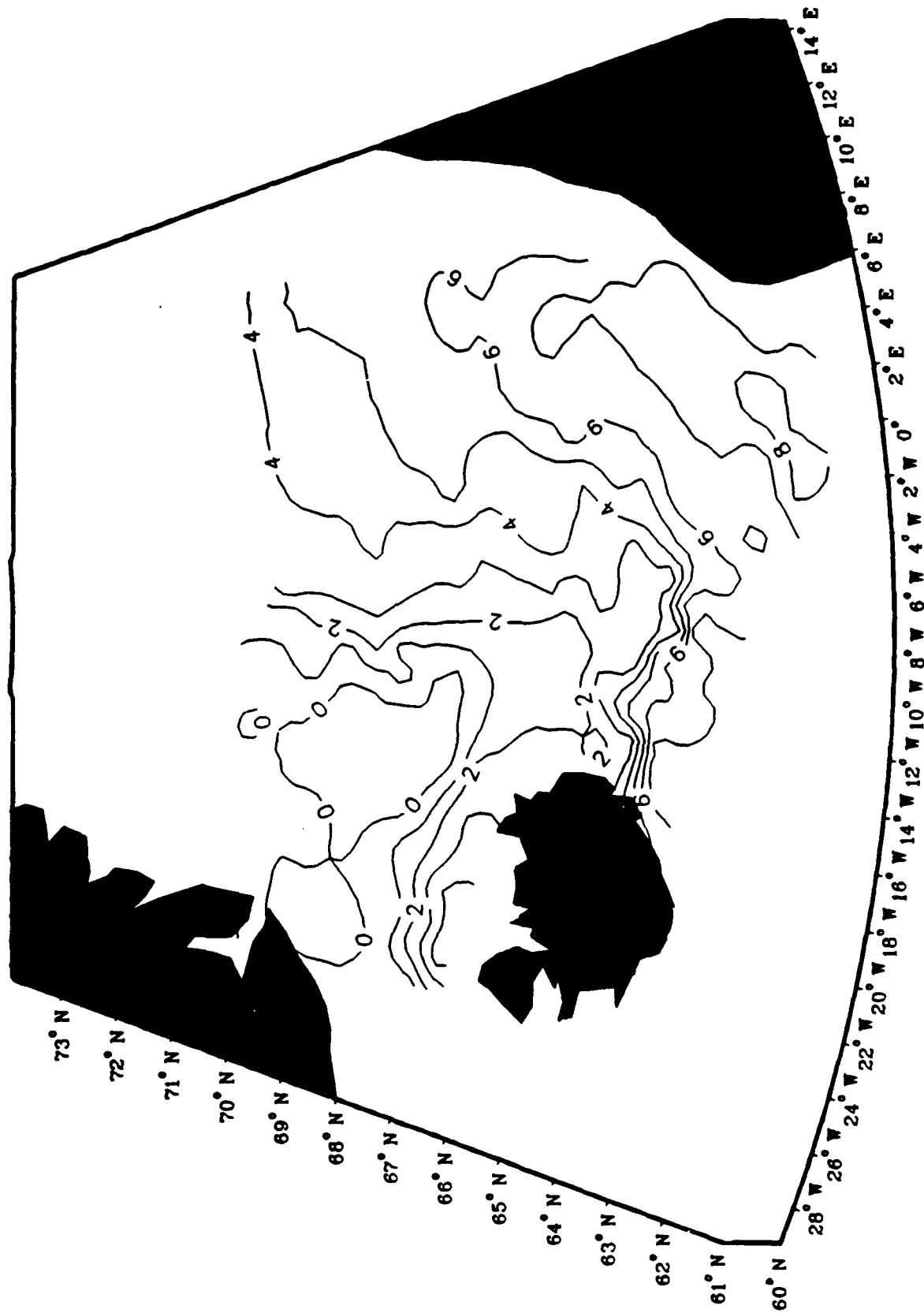
GIN Sea Survey, May 1987
AXBT Stations



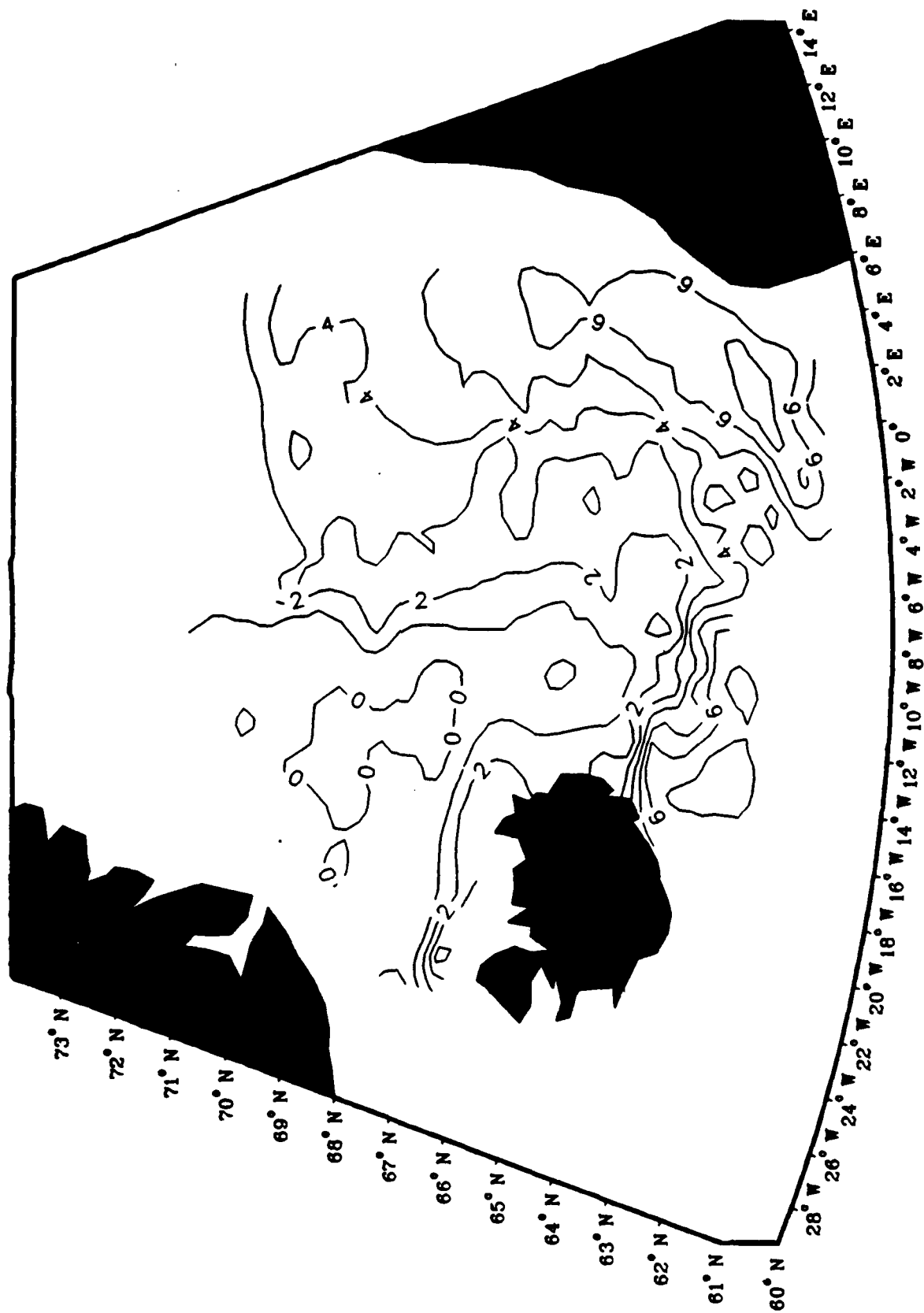
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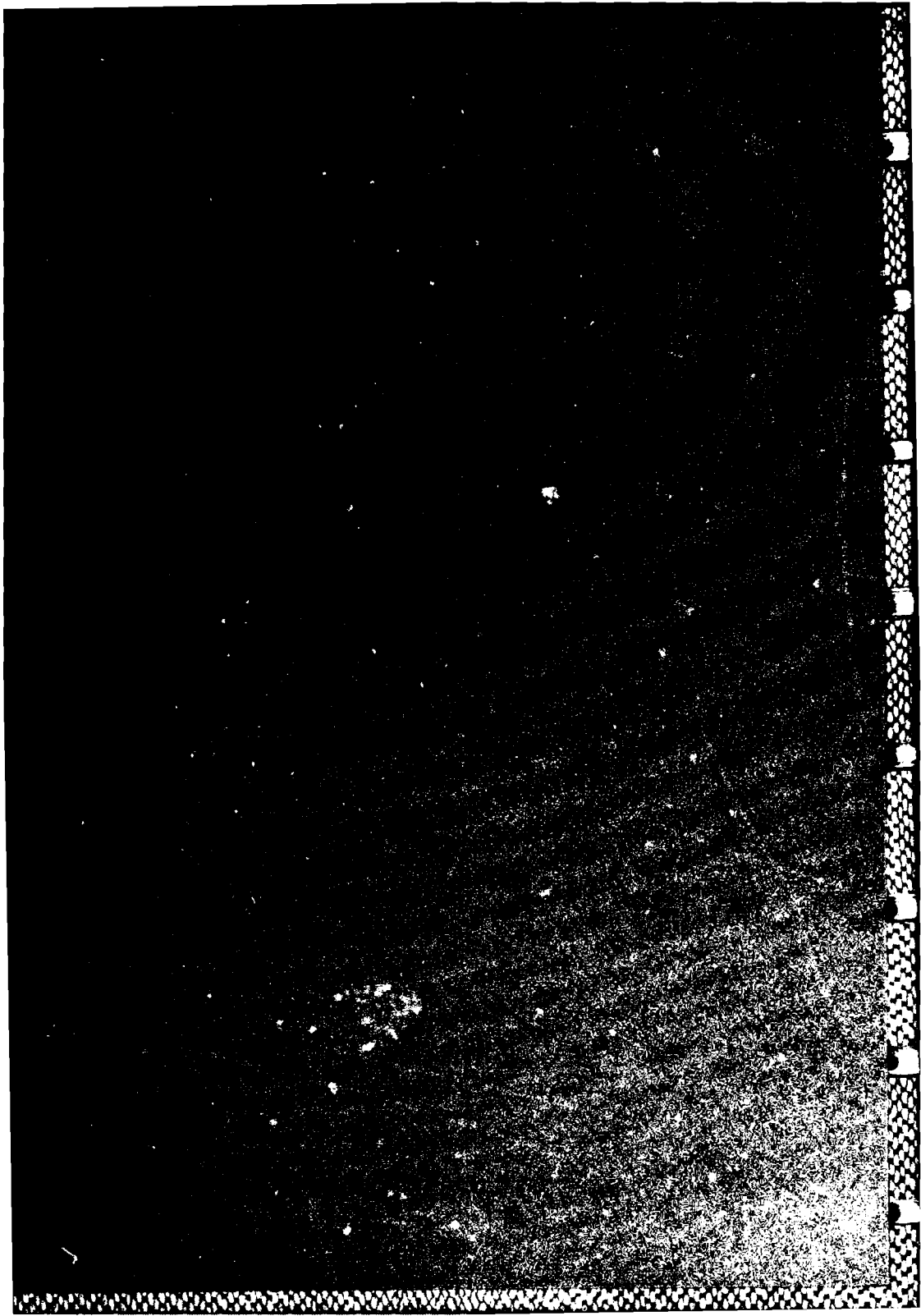
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Temperature
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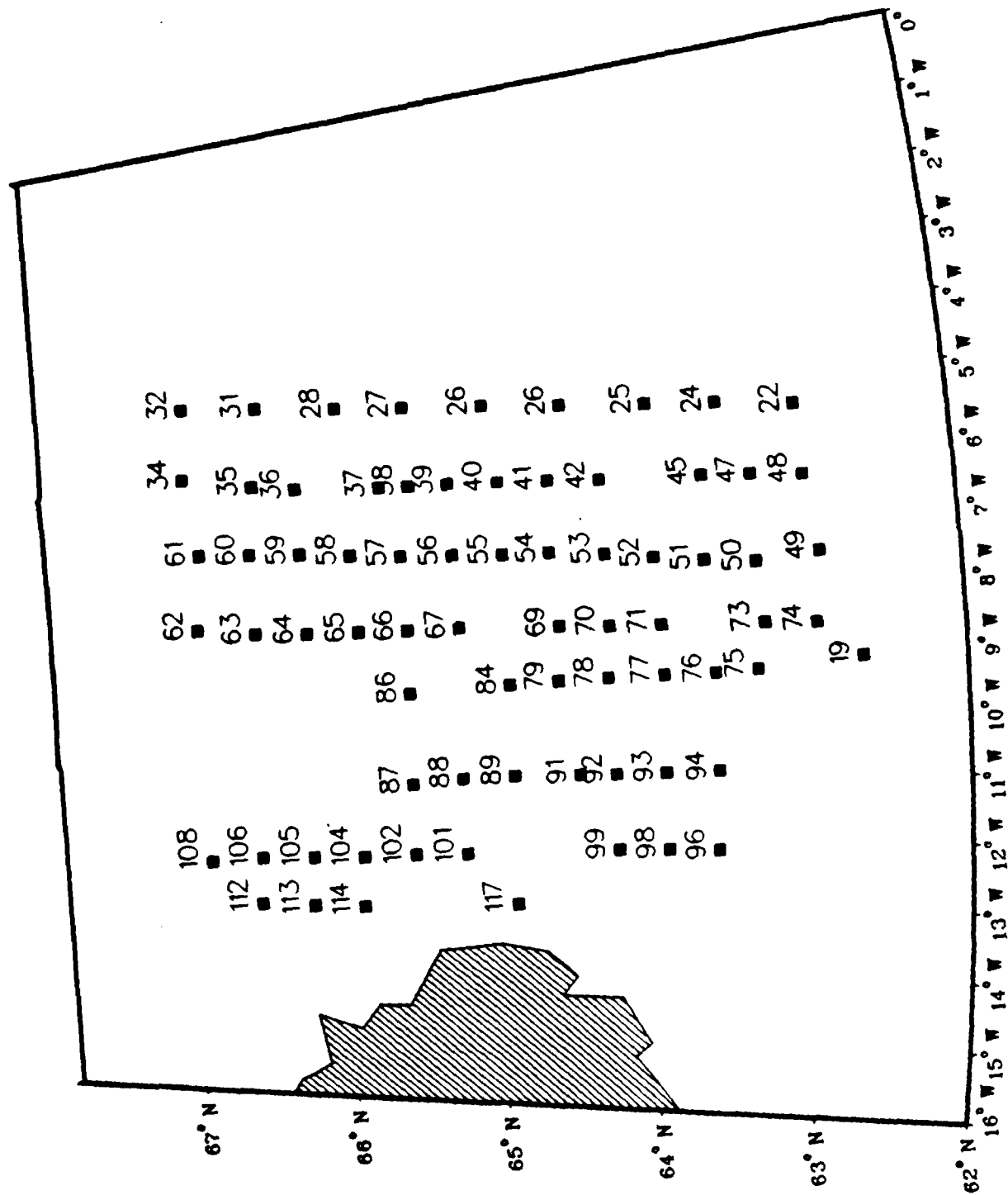
Map of the North Atlantic showing isobars of surface salinity. The map covers the region from 60°N to 73°N and 28°W to 14°E. Landmasses are shown in black. Isobars are labeled with values 0, 2, 4, 6, and 8. The map shows a salinity minimum (0) in the central North Atlantic and a maximum (8) in the northeast.



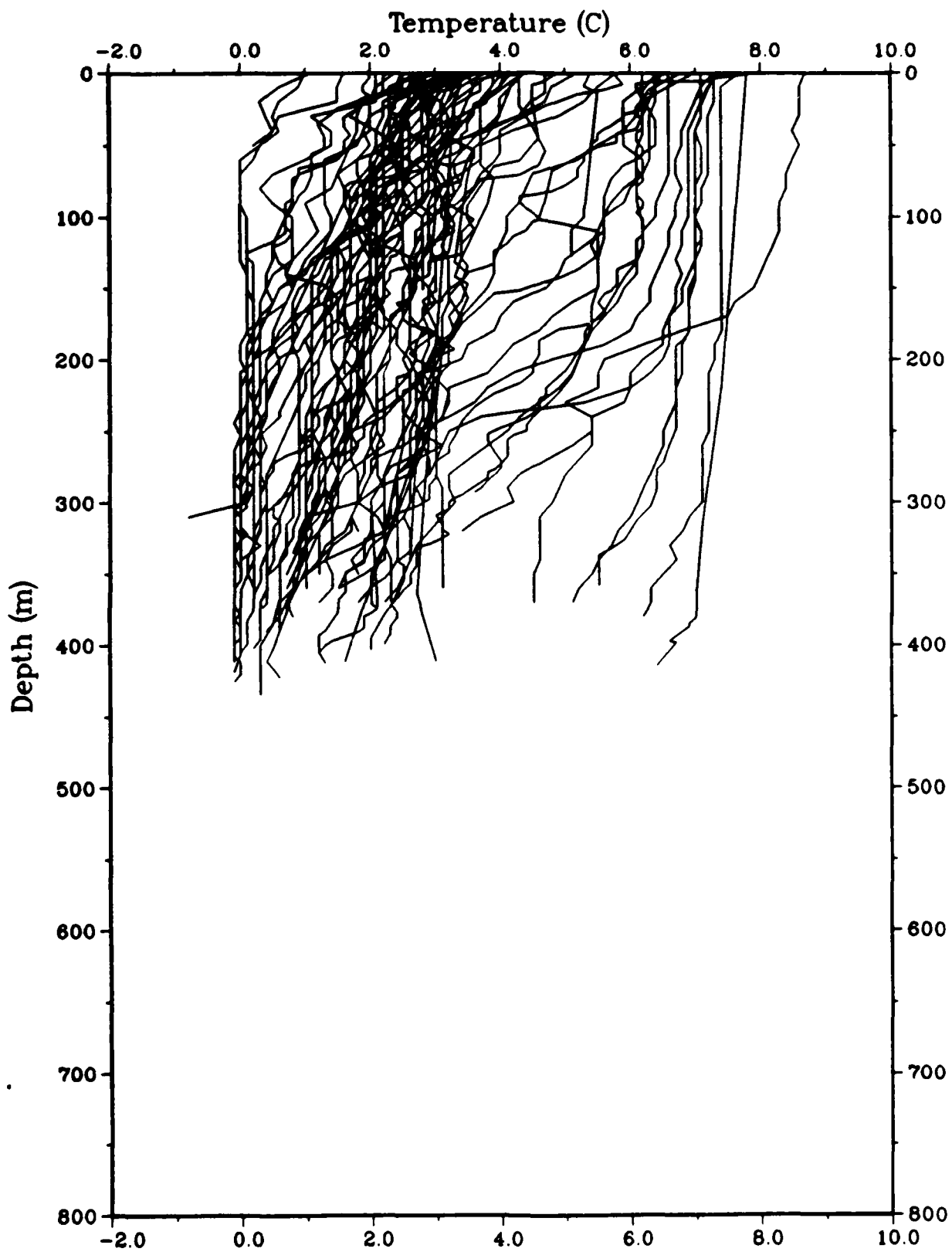
**Island-Palooa Frontal Zone
Survey #1**

15 May 1987

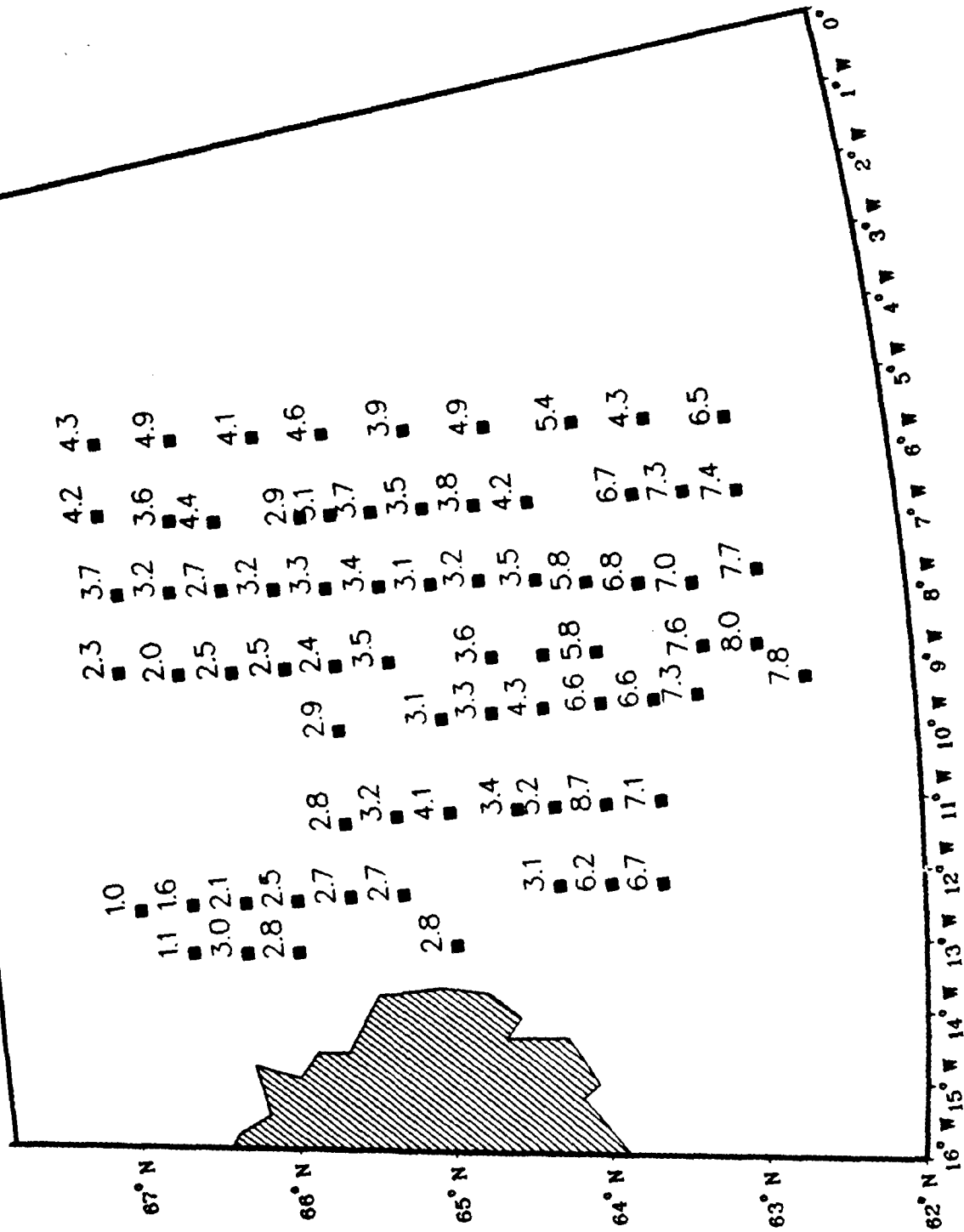
15 May 1987 AXBT Stations



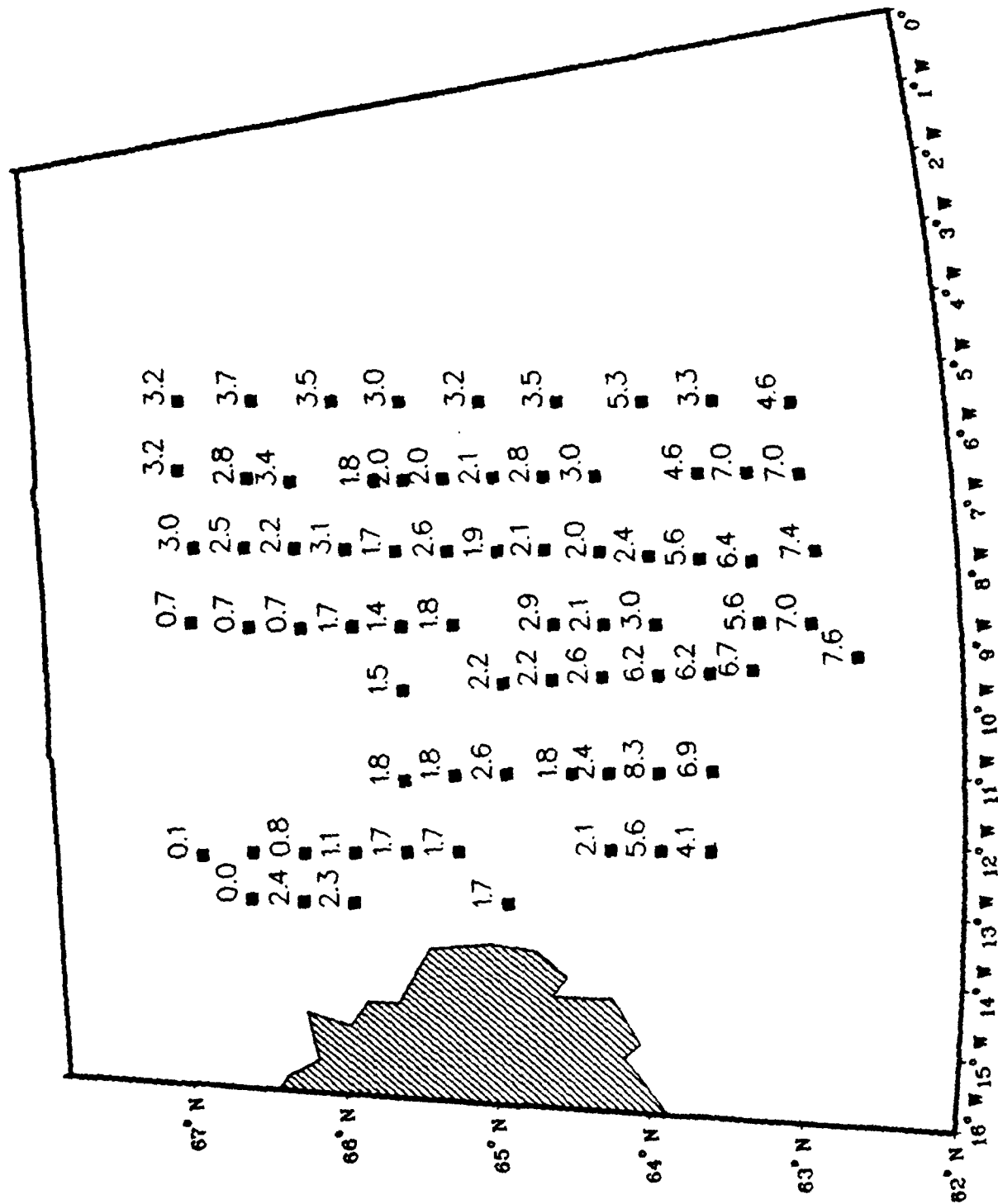
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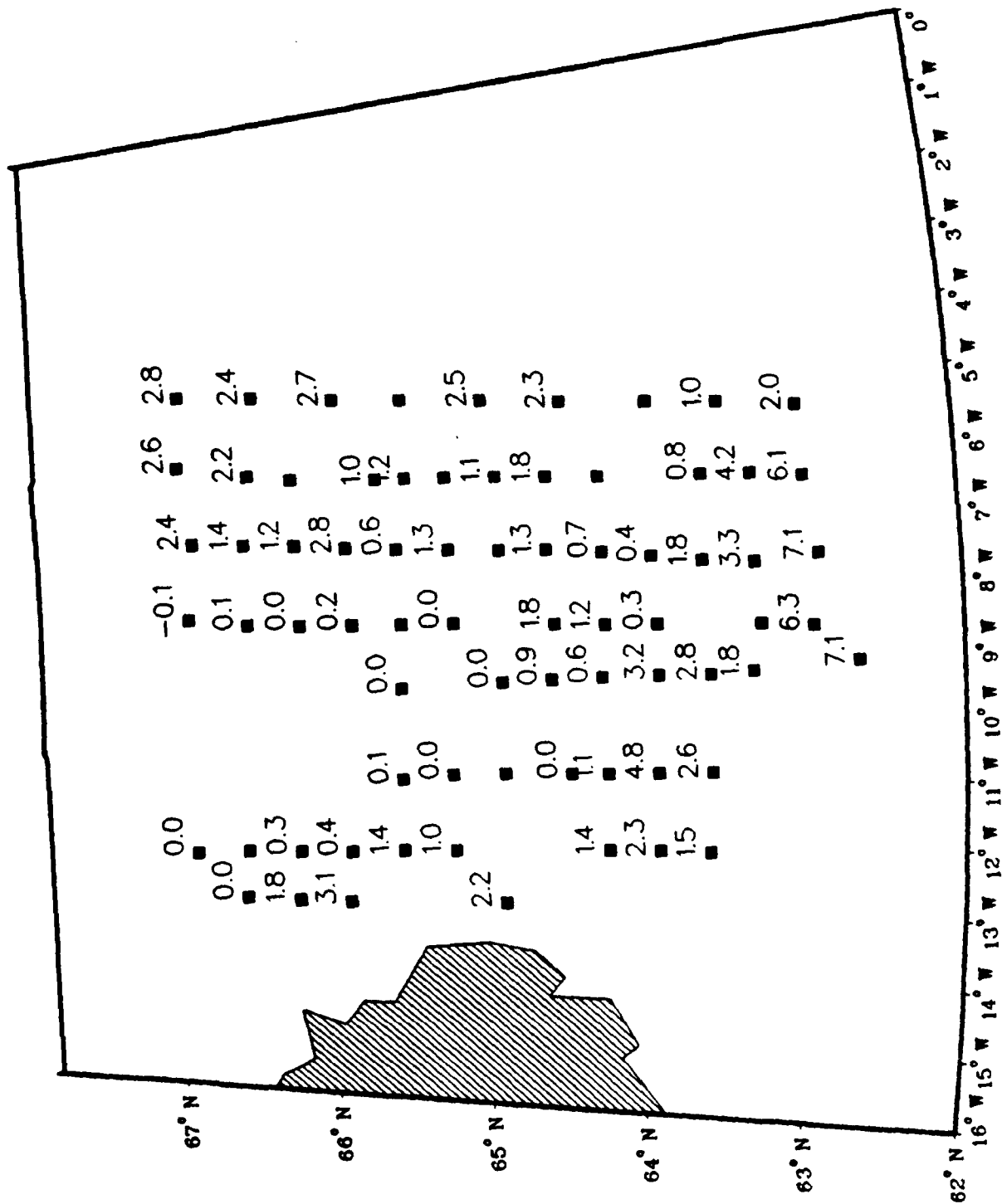
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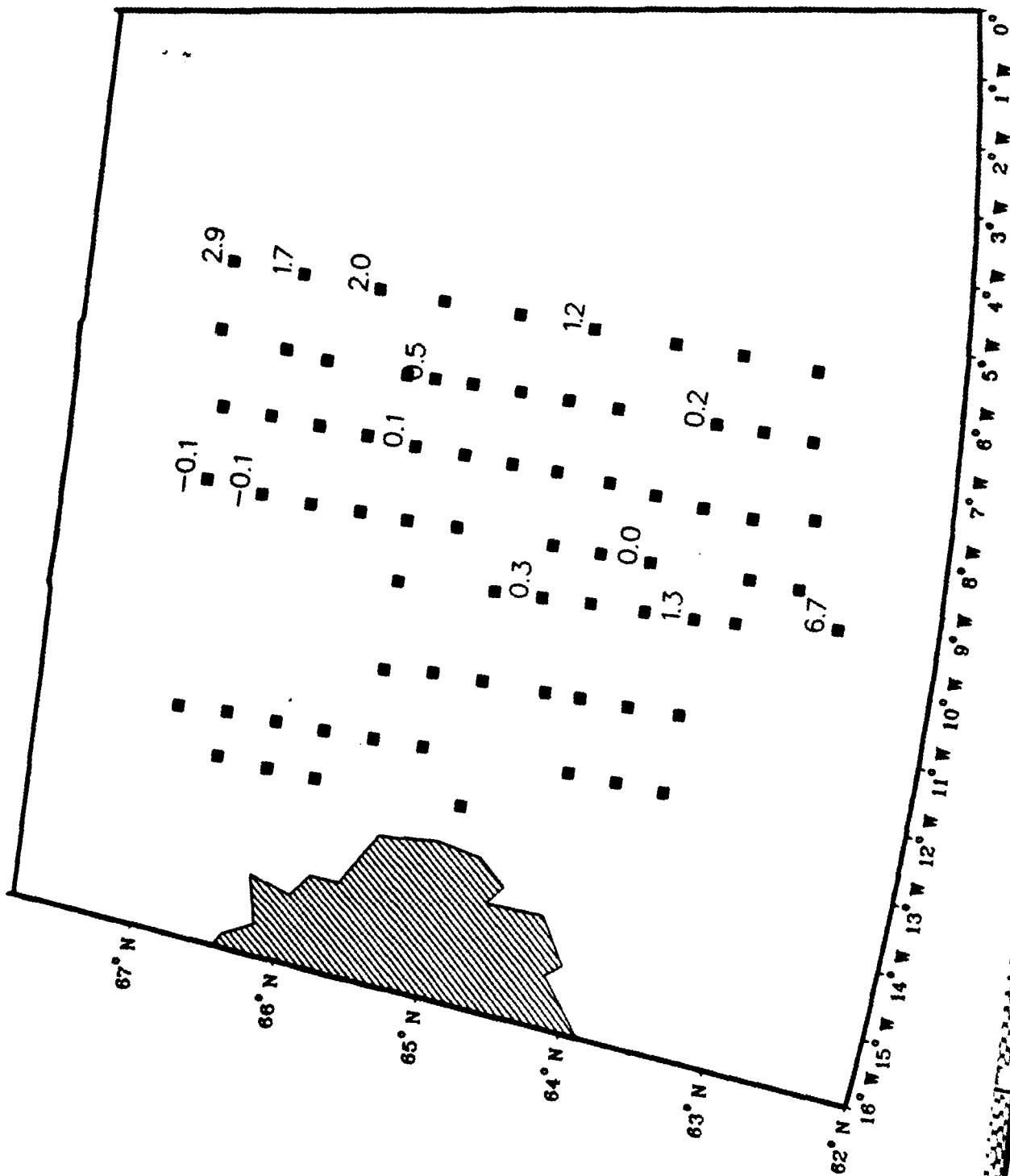
Map of the North Atlantic Ocean showing temperature data points. The map covers latitudes from 62°N to 67°N and longitudes from 0°W to 16°W. A shaded area represents land (North America) in the upper left. Data points are represented by numbers and small squares. The numbers are arranged in a grid-like pattern, with some values repeated. The map is oriented with latitude on the vertical axis and longitude on the horizontal axis.

| Latitude | 0°W | 1°W | 2°W | 3°W | 4°W | 5°W | 6°W | 7°W | 8°W | 9°W | 10°W | 11°W | 12°W | 13°W | 14°W | 15°W | 16°W |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|
| 67°N | 0.1 | 0.2 | 0.6 | 0.2 | 2.8 | 2.9 | 3.1 | 3.0 | 3.1 | | | | | | | | |
| 66°N | 0.1 | 0.6 | 0.2 | 0.6 | 2.7 | 3.1 | 2.7 | 1.6 | 1.8 | 1.9 | 2.0 | 1.9 | 2.3 | 3.0 | | | |
| 65°N | 0.1 | 0.6 | 0.2 | 0.6 | 2.7 | 3.1 | 2.7 | 1.6 | 1.8 | 1.9 | 2.0 | 1.9 | 2.3 | 3.0 | | | |
| 64°N | 0.1 | 0.6 | 0.2 | 0.6 | 2.7 | 3.1 | 2.7 | 1.6 | 1.8 | 1.9 | 2.0 | 1.9 | 2.3 | 3.0 | | | |
| 63°N | 0.1 | 0.6 | 0.2 | 0.6 | 2.7 | 3.1 | 2.7 | 1.6 | 1.8 | 1.9 | 2.0 | 1.9 | 2.3 | 3.0 | | | |

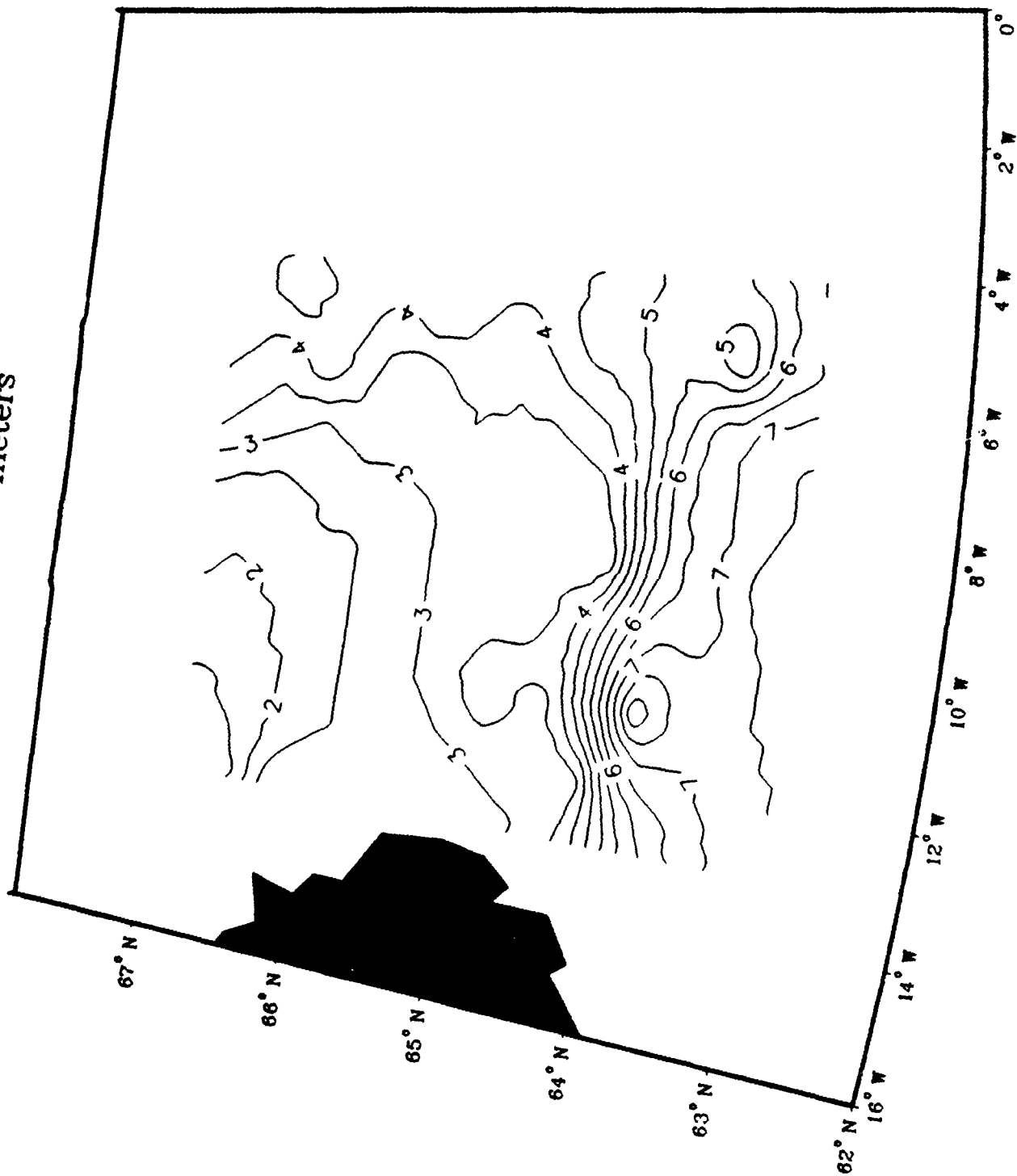
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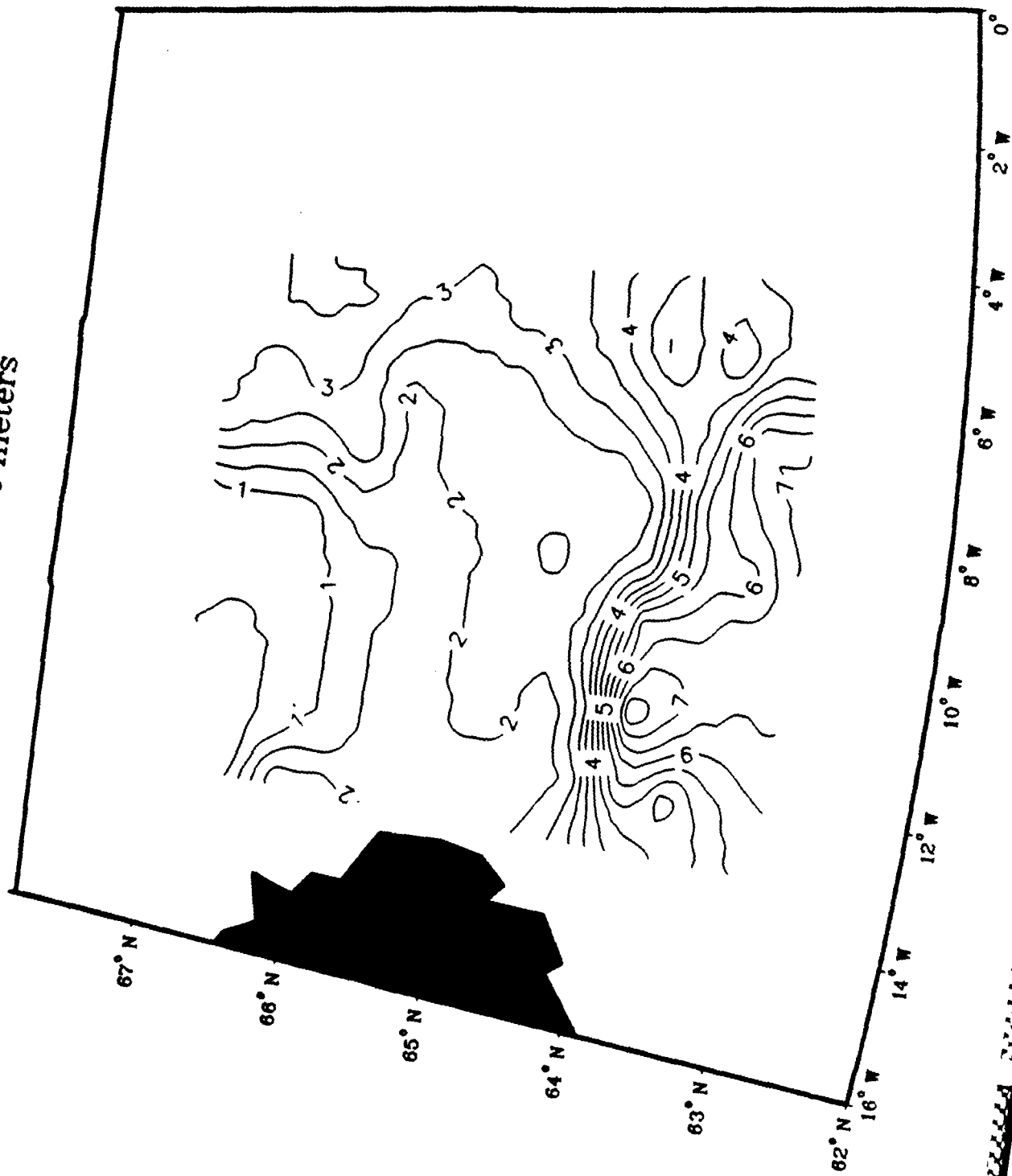
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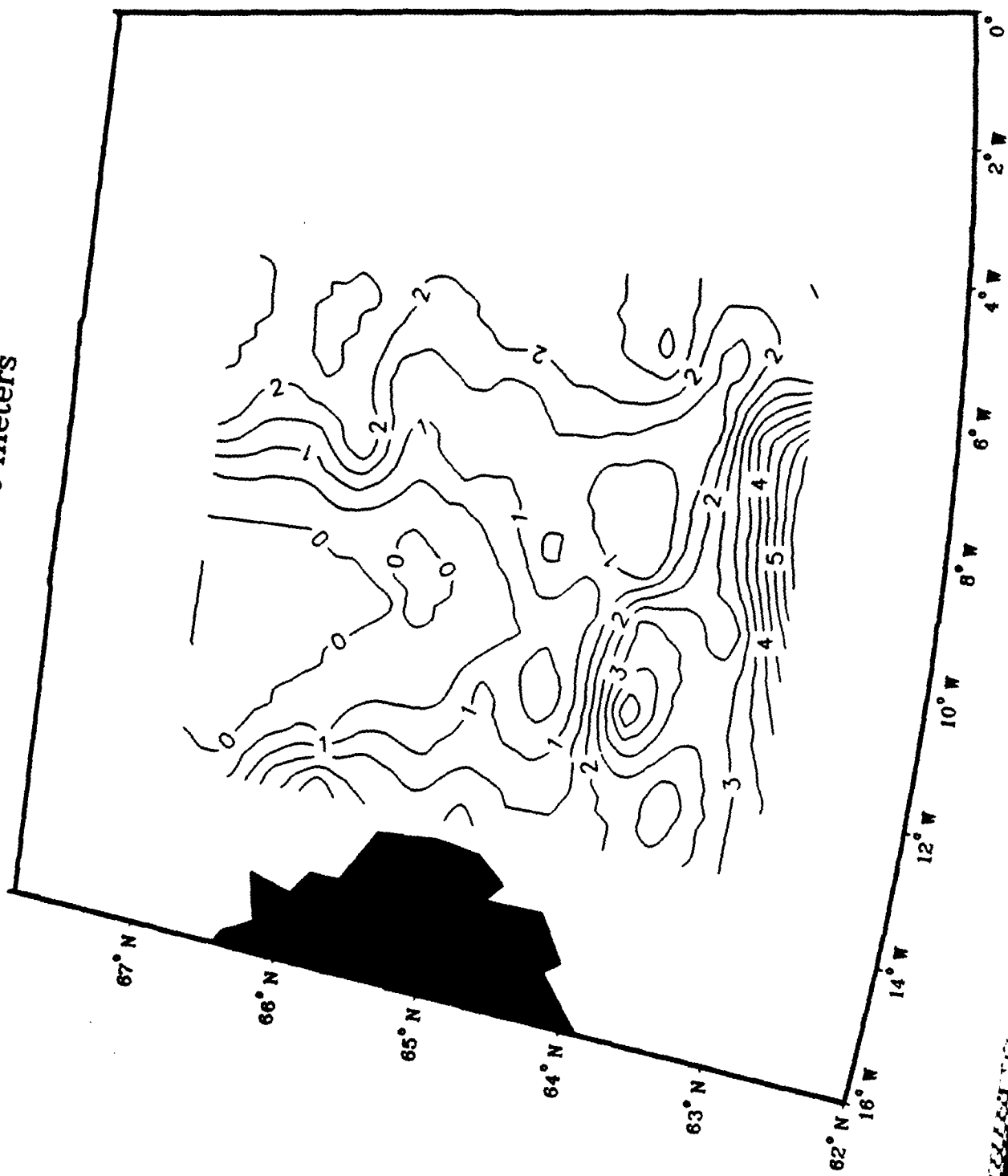
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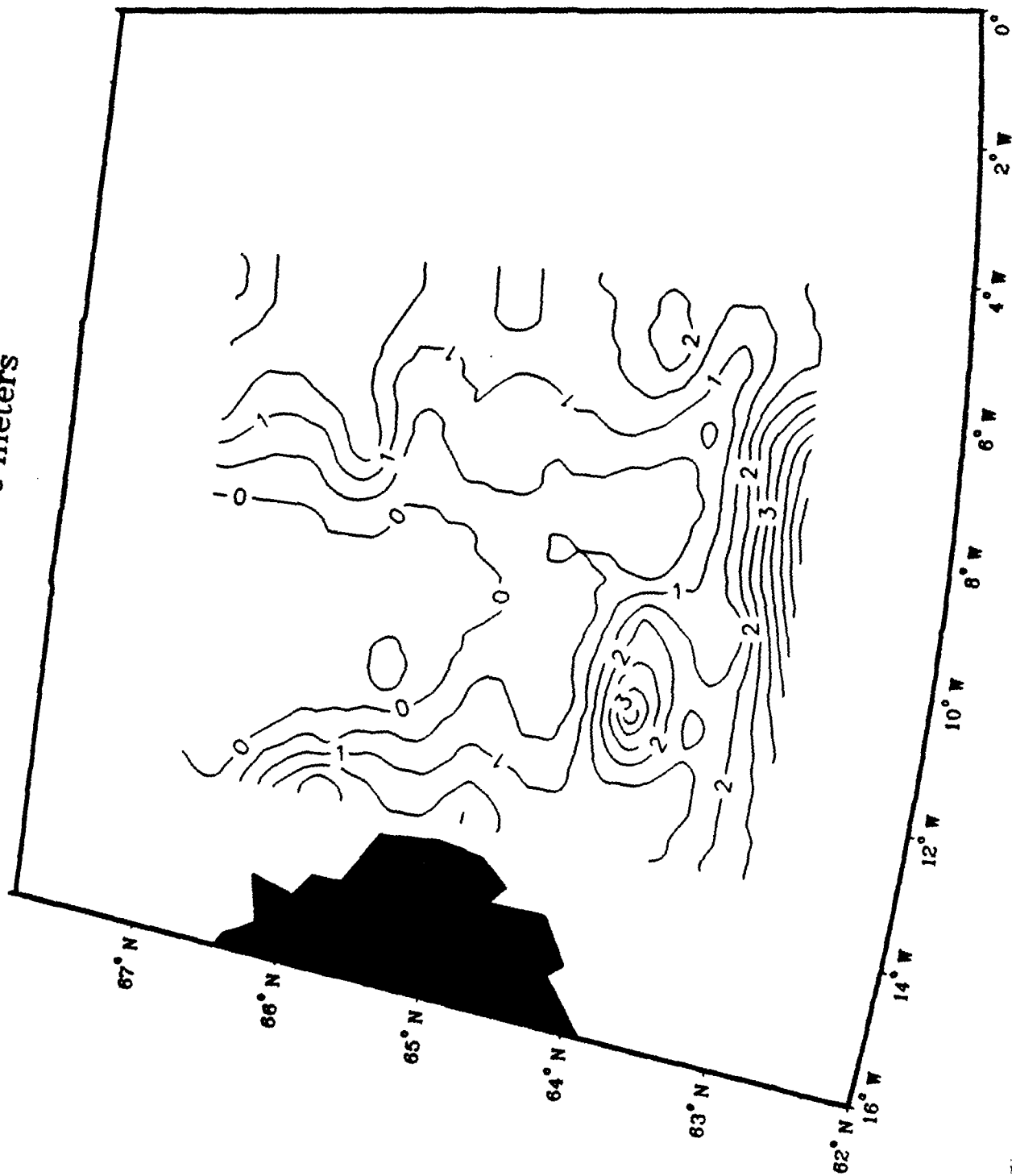
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Temperature
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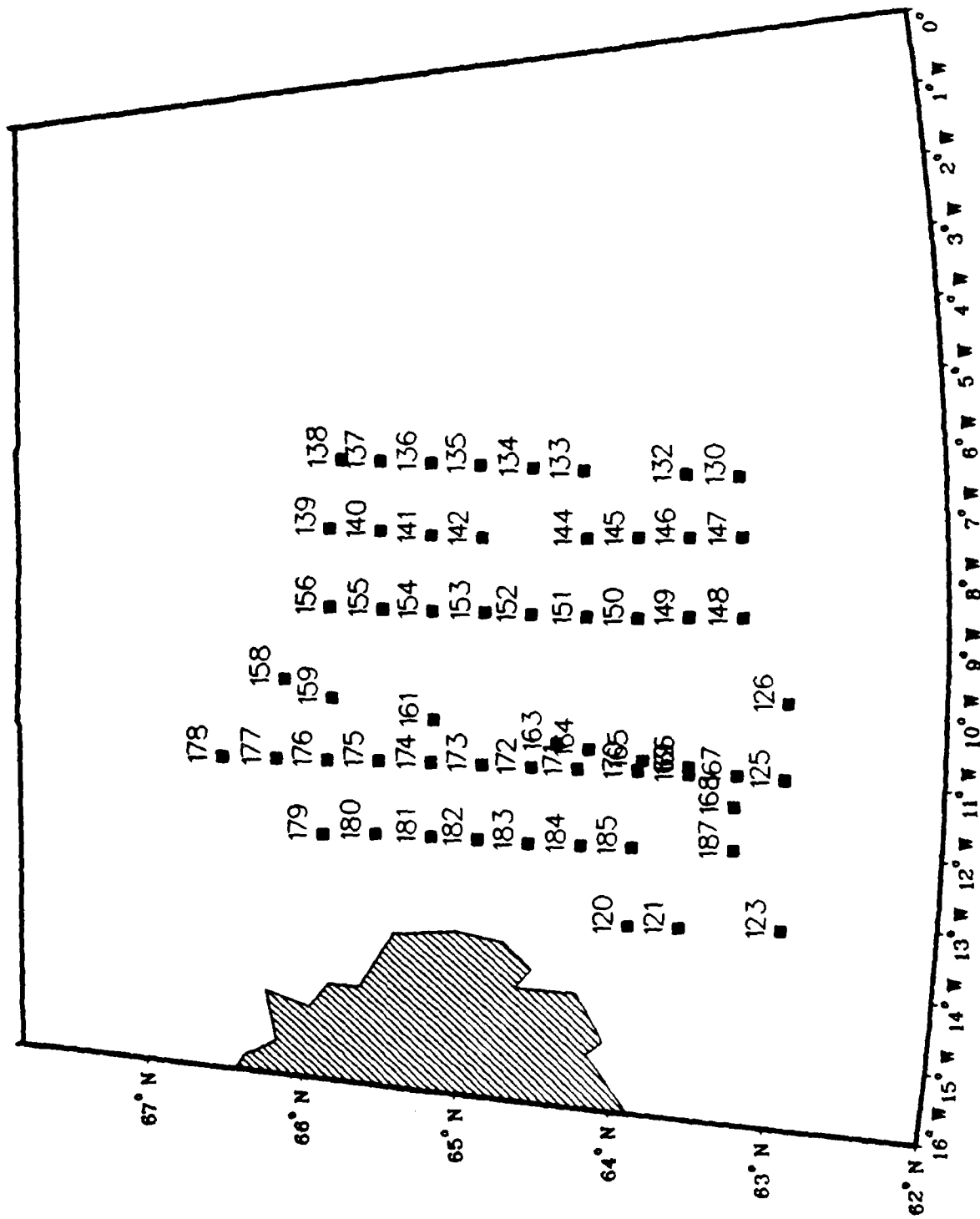
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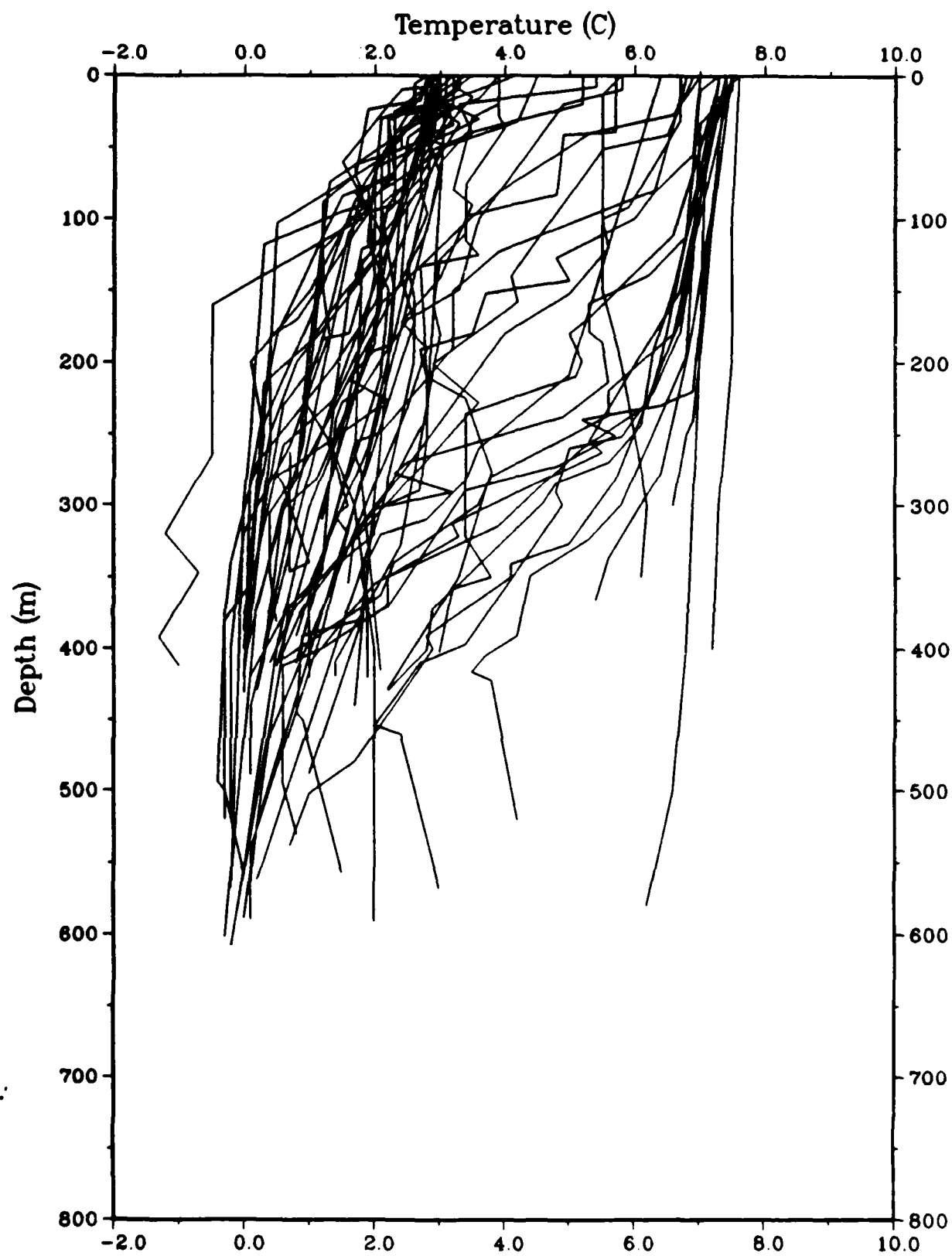
**Iceland-Faeroe Frontal Zone
Survey #2**

18 May 1987

18 May 1987 AXBT Stations



18 May 1987



Map of the study area in the North Atlantic, showing latitude from 62°N to 67°N and longitude from 0° to 16°W. A shaded region indicates the location of the study area, roughly between 64°N and 66°N latitude and 12°W and 14°W longitude. Data points are plotted as small squares with numerical values, showing a general trend of increasing values from west to east and from south to north.

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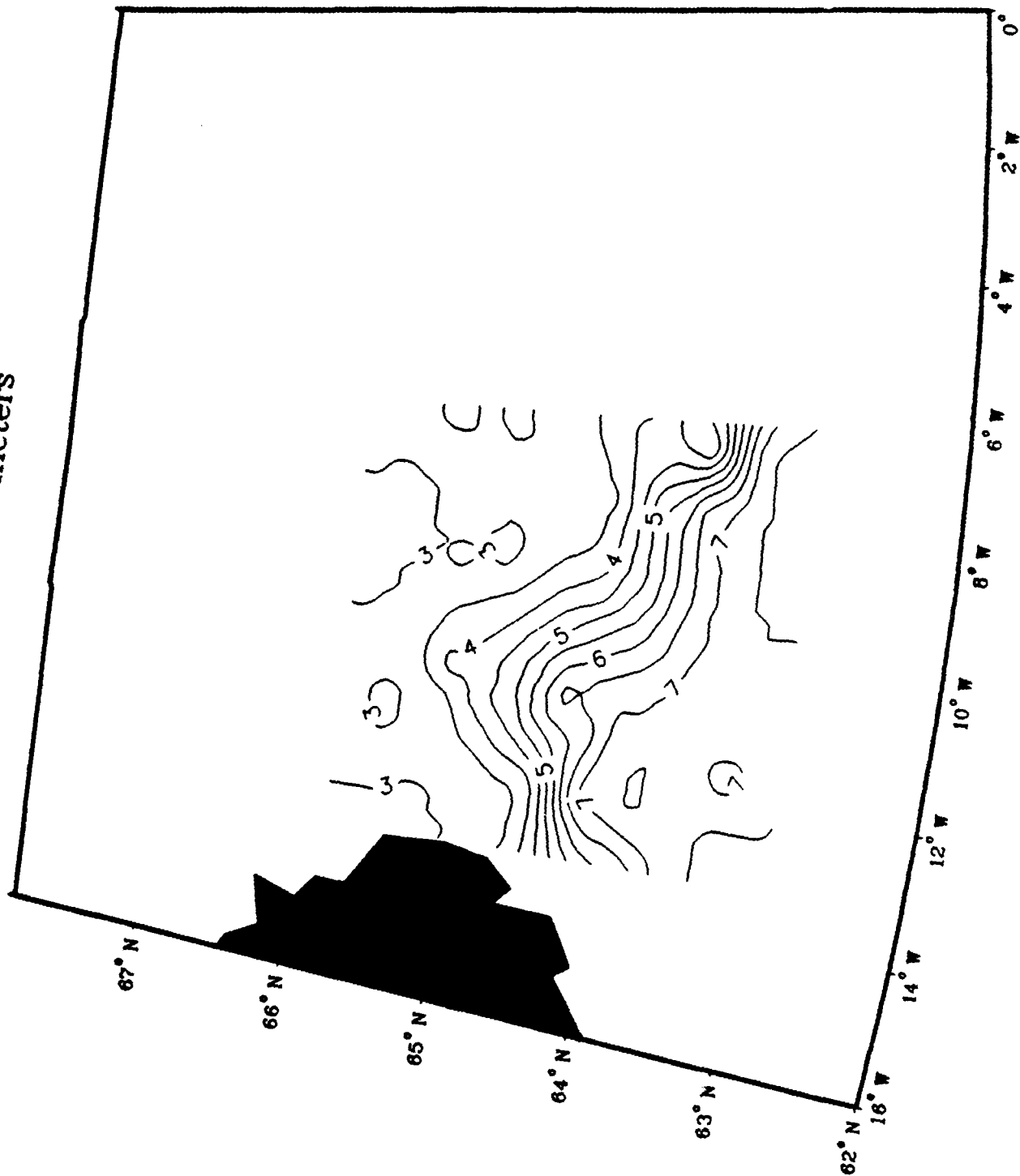
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Map of the North Atlantic Ocean showing temperature data points. The map covers latitudes from 62°N to 67°N and longitudes from 16°W to 0° (Prime Meridian). A shaded area represents land (North America) on the left. Data points are plotted as small squares with numerical values. The values range from -0.5 to 7.5. The data points are organized in a grid-like pattern across the ocean area.

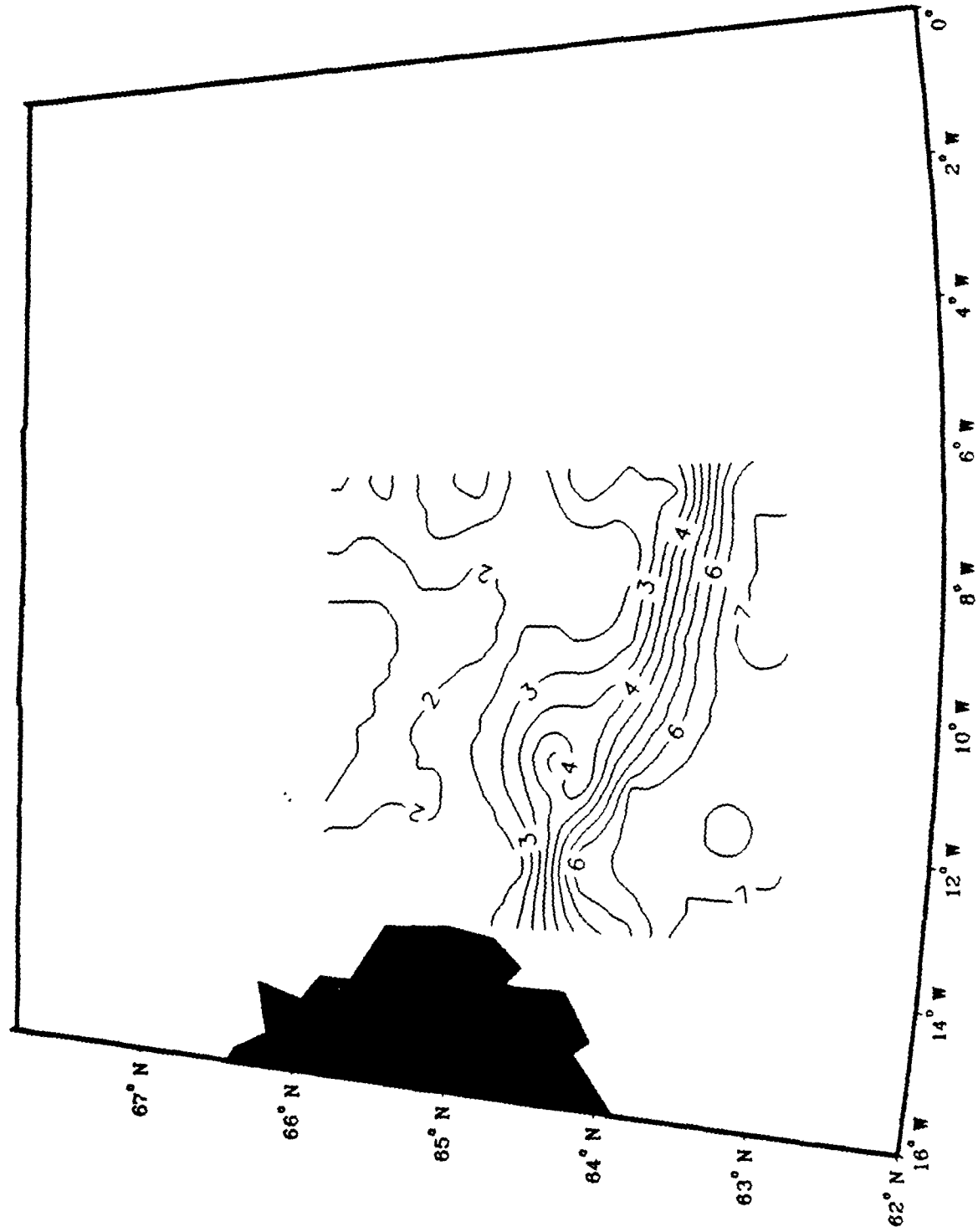
Map of the North Atlantic Ocean showing temperature and salinity data points. The map covers latitudes from 62°N to 67°N and longitudes from 0° to 16°W. A shaded area represents land (North America). Data points are plotted as small squares with numerical values. The values range from -0.9 to 7.3. The data points are organized into a grid-like pattern, with values generally increasing from west to east and from south to north.

A map of the Sargasso Sea region, bounded by 62°N to 67°N latitude and 0°W to 16°W longitude. The map displays temperature data points (isotherms) for various depths, with values ranging from -12.0 to 12.0. A shaded area, likely representing a specific oceanographic feature or data boundary, is visible in the upper right quadrant, roughly between 64°N to 66°N and 12°W to 15°W. The data points are labeled with numerical values, some of which are repeated, indicating specific temperature readings at different locations.

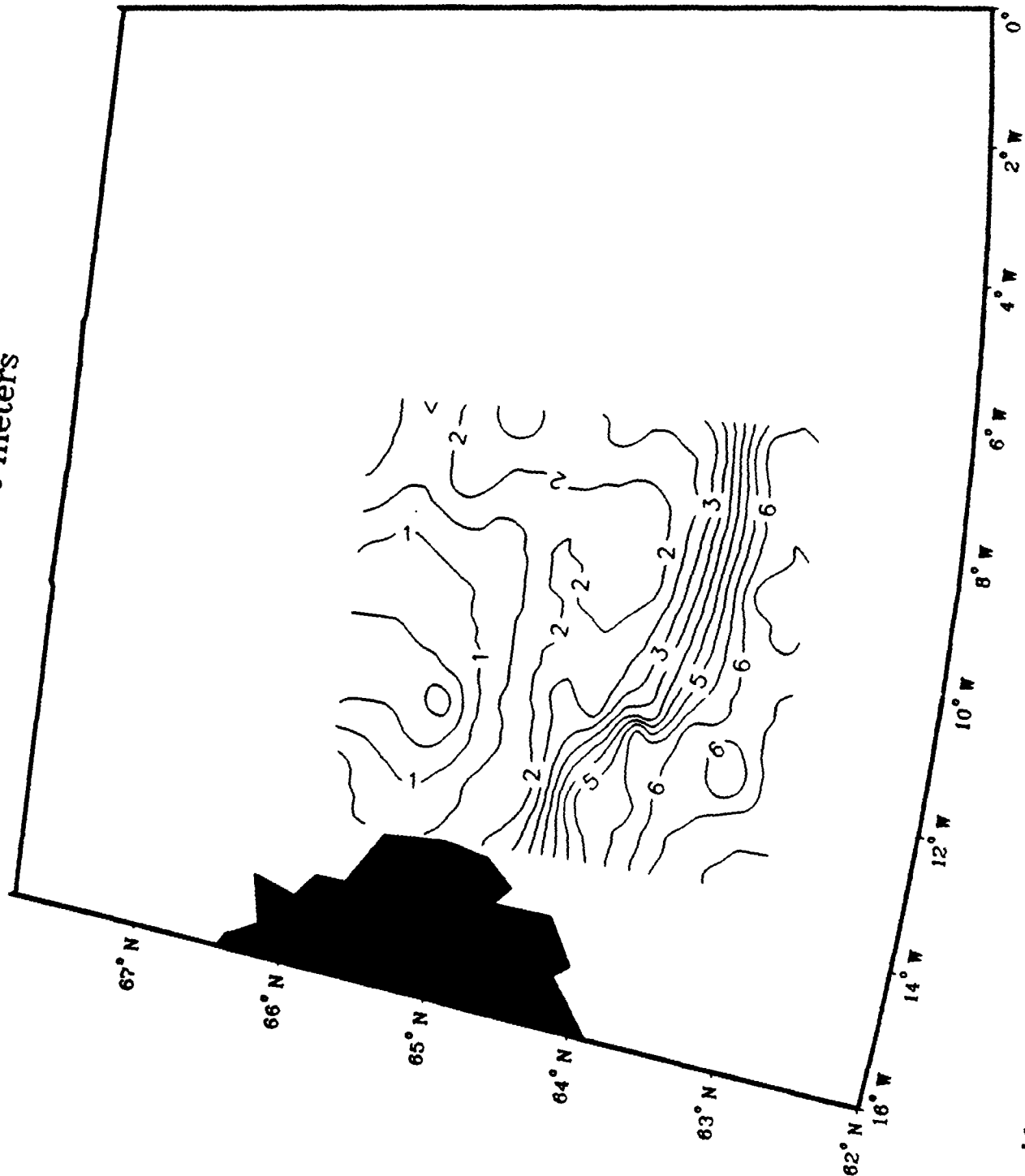
Temperature
18 May 1987
0 meters



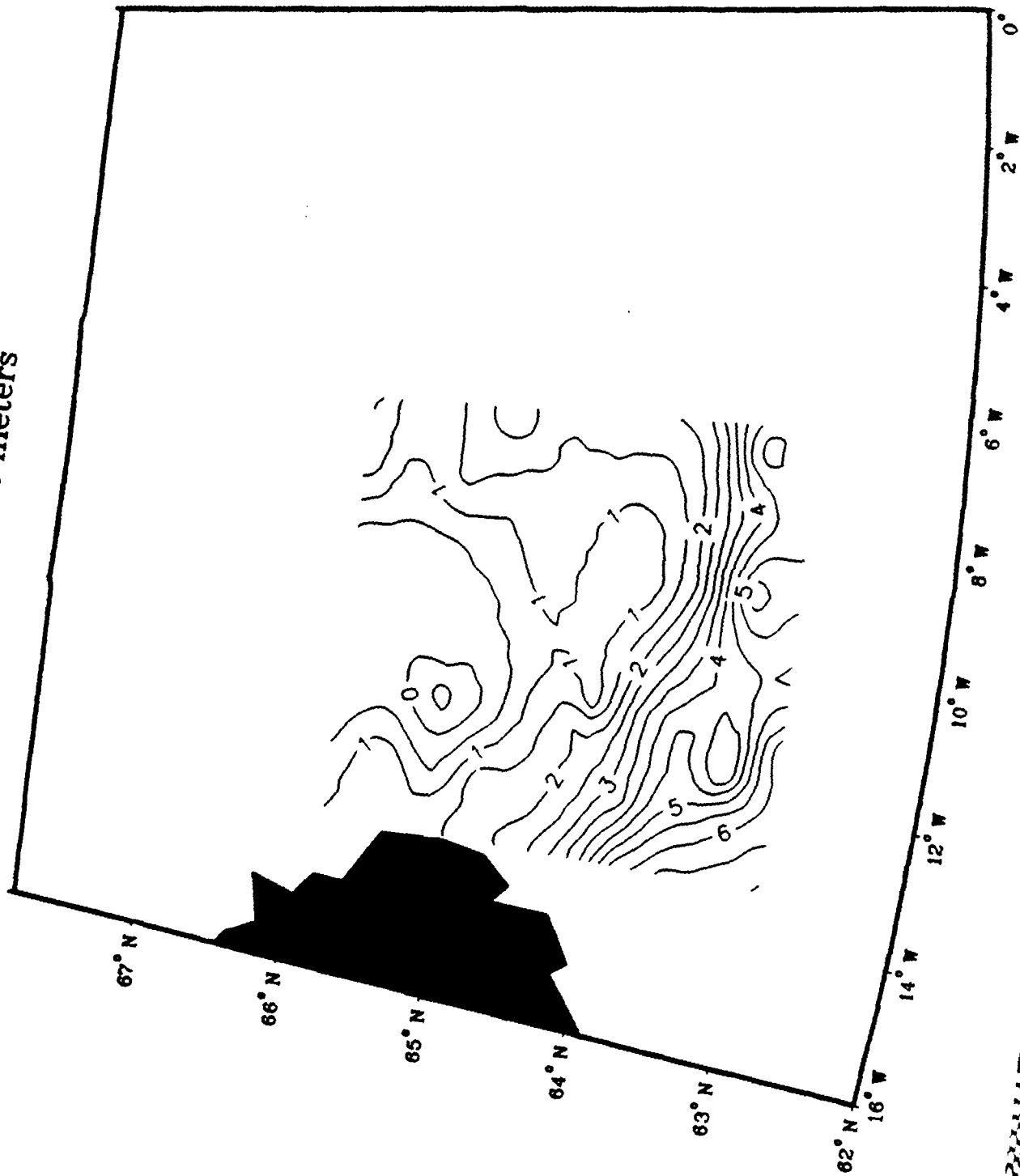
Temperature
18 May 1987
100 meters



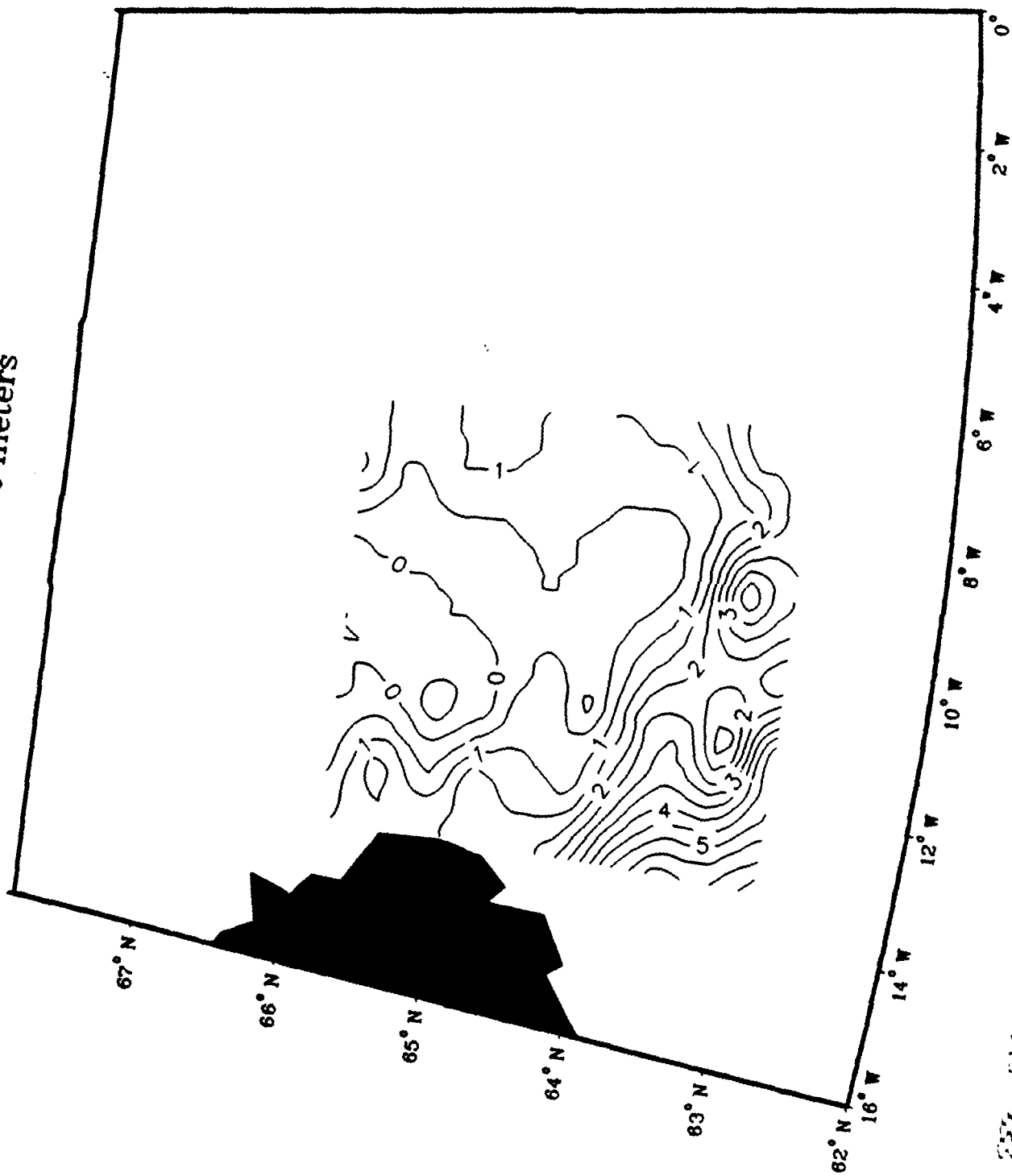
Temperature
18 May 1987
200 meters



Temperature
18 May 1987
300 meters



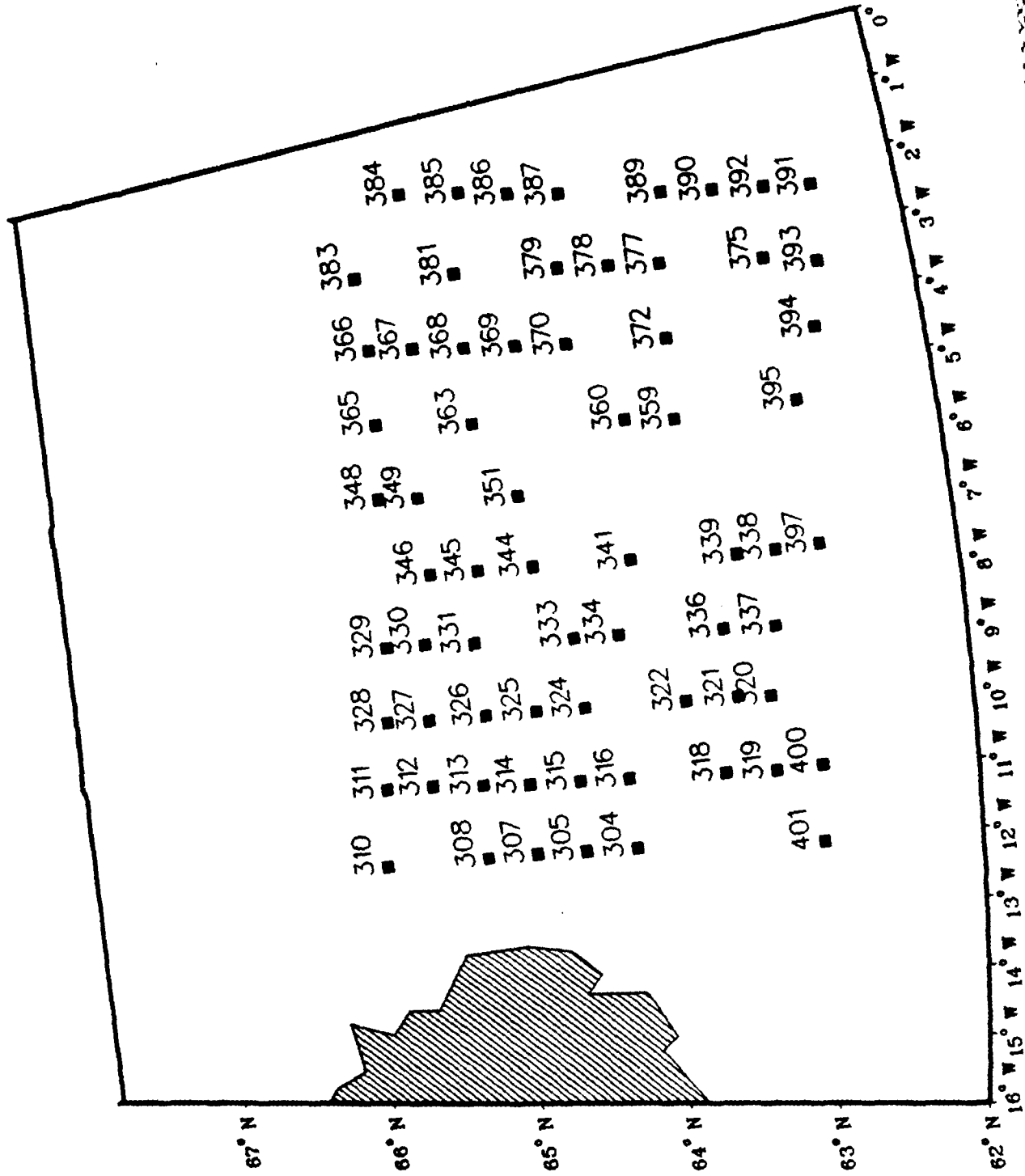
Temperature
18 May 1987
400 meters



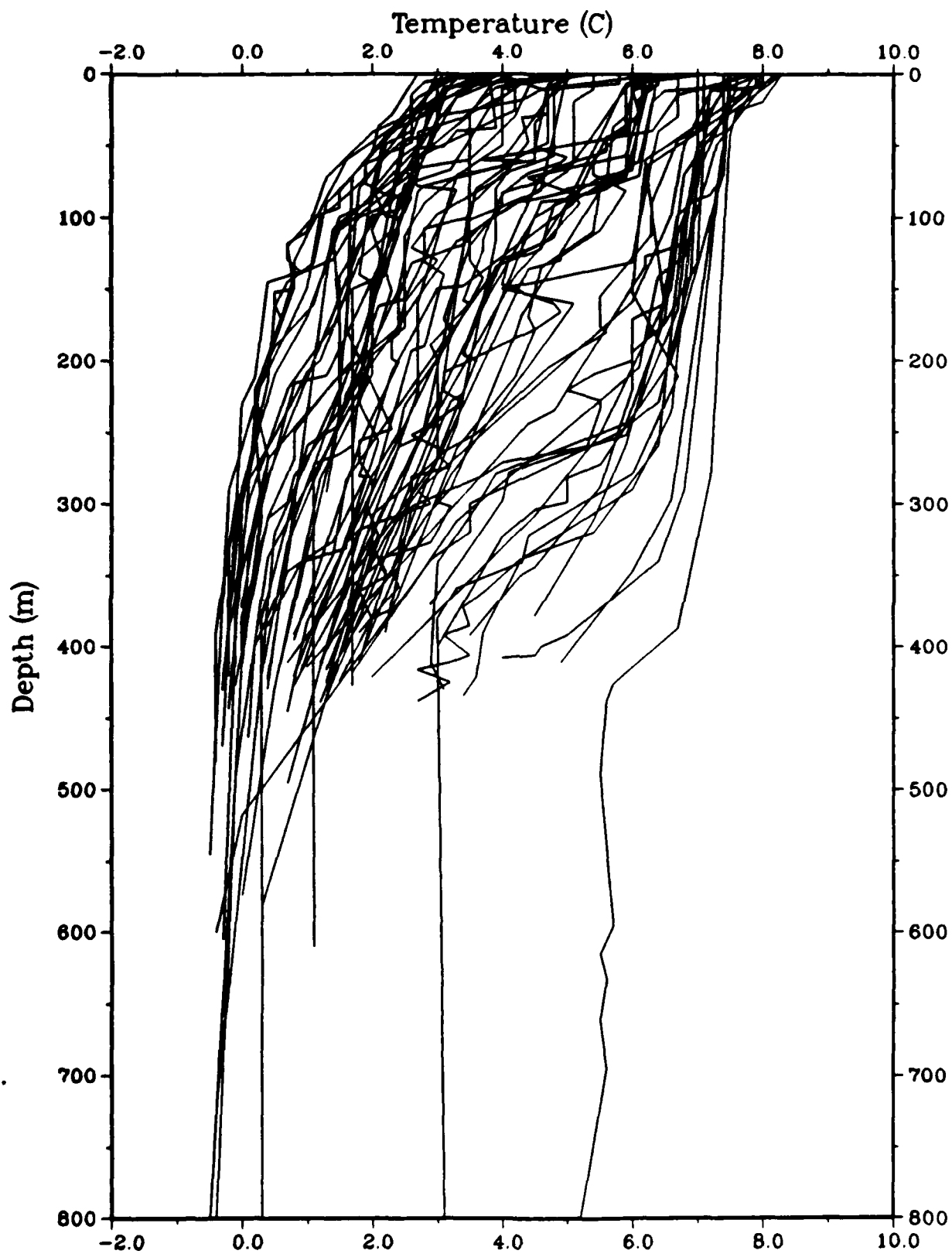
**Feeder Frontal Zone
Survey #3**

22 May 1987

22 May 1987 AXBT Stations

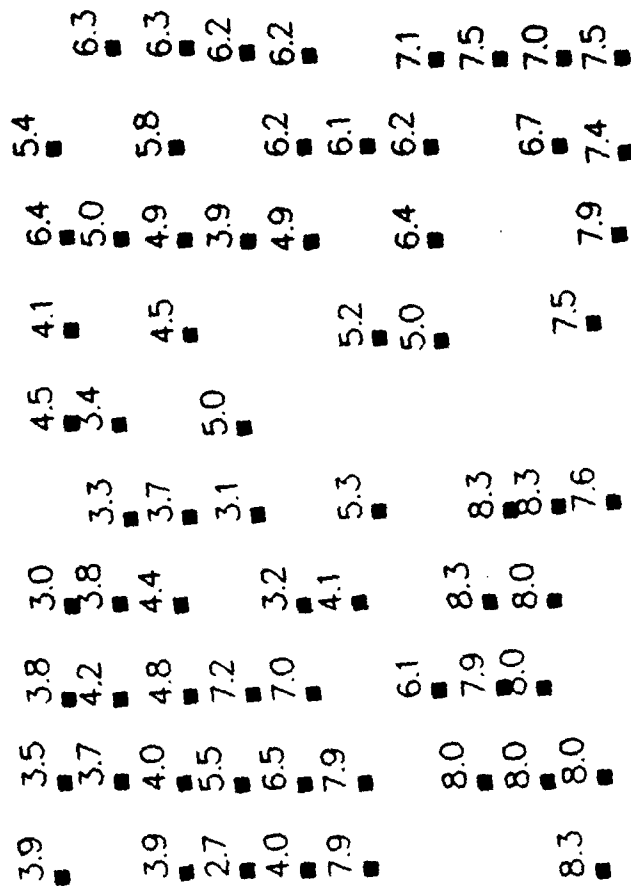


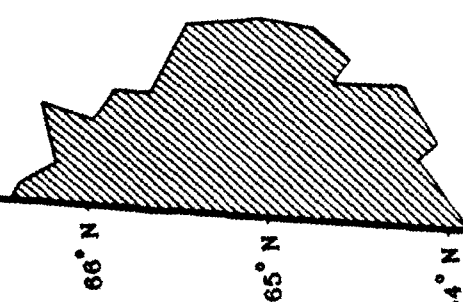
22 May 1987



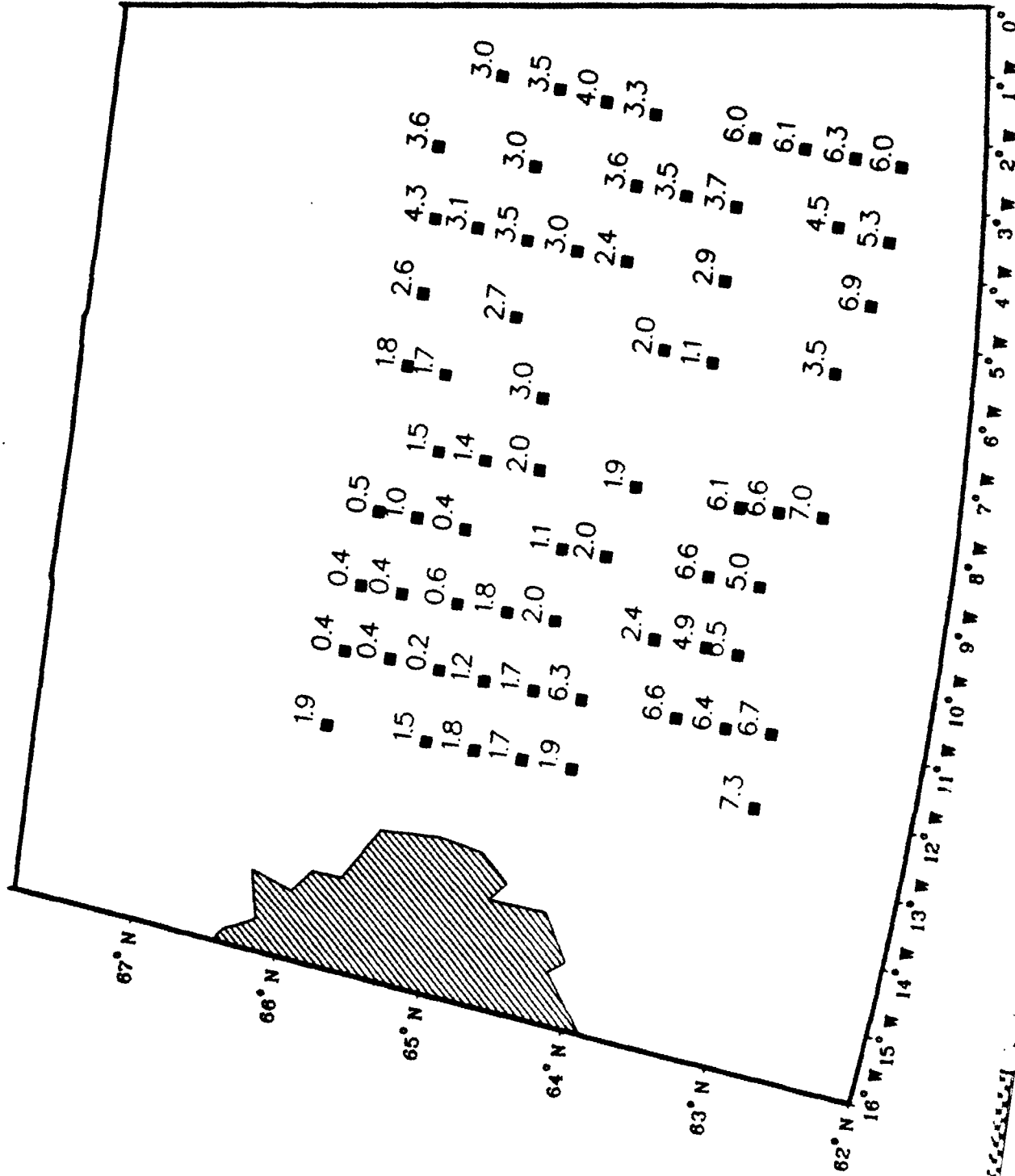
62.2

16° W 15° W 14° W 13° W 12° W 11° W 10° W 9° W 8° W 7° W 6° W



[illegible]

22 May 1987
200 meters



121



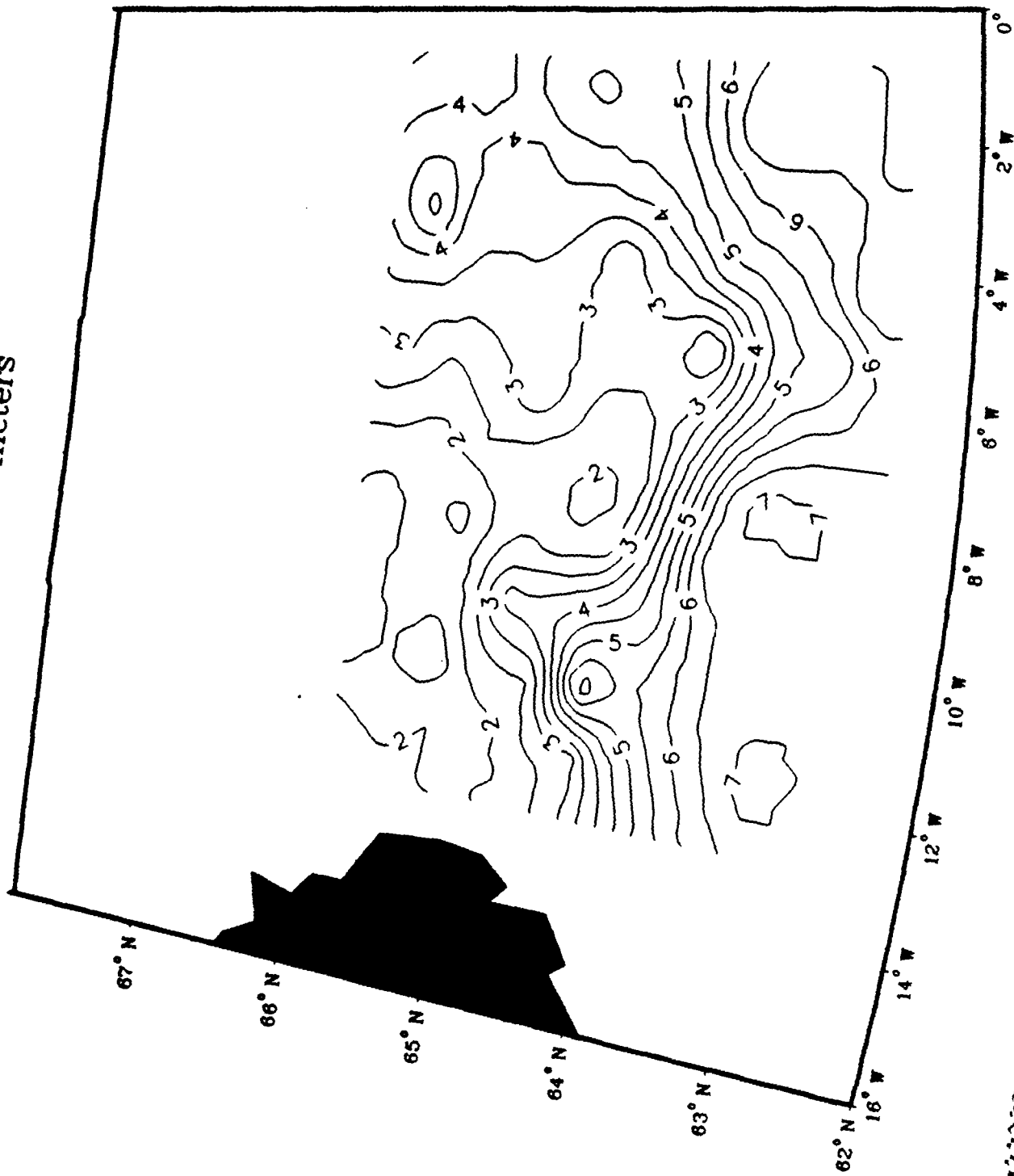
22 May 1987
400 meters



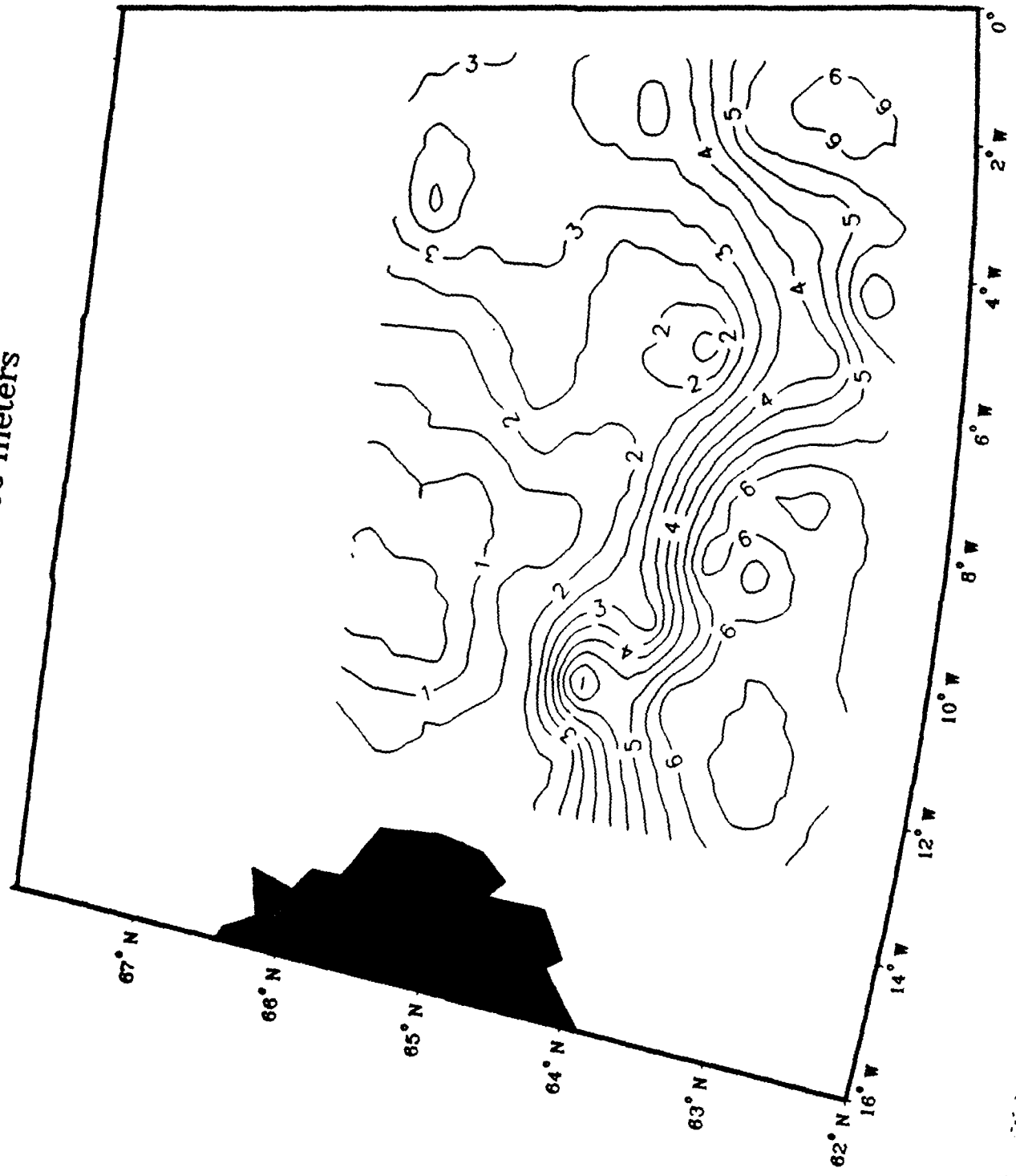
This map displays the 1000-m depth isotherms in the North Atlantic. The geographic area is defined by latitudes 62°N to 67°N and longitudes 16°W to 0°W. The isotherms are labeled with their corresponding temperature values: 4, 5, 6, 7, and 8. The map shows a complex pattern of isotherms, with a prominent feature of high values (8) in the central-eastern part of the domain, likely representing the Gulf Stream. A large black area in the upper left corner indicates the landmass of Greenland.

| | | | | | | | | | | | | | | | | | | | |
|----|----|---|----|----|----|----|----|----|---|---|----|----|-----|----|----|---|---|----|---|
| 34 | 22 | 1 | 35 | 16 | 65 | 35 | 28 | 51 | 1 | 1 | 12 | 22 | 157 | 24 | 55 | 5 | 1 | 22 | 1 |
|----|----|---|----|----|----|----|----|----|---|---|----|----|-----|----|----|---|---|----|---|

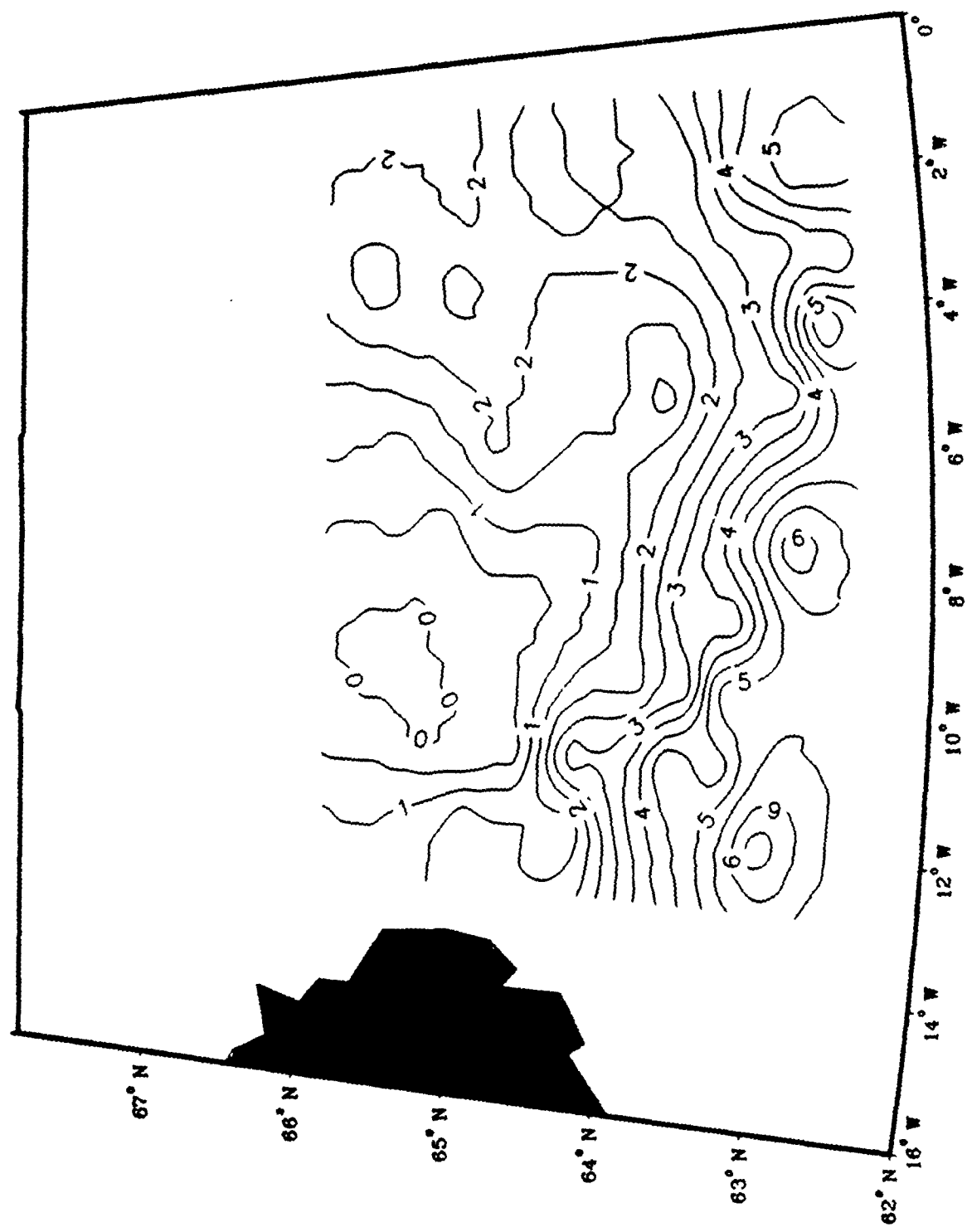
Temperature
22 May 1987
100 meters



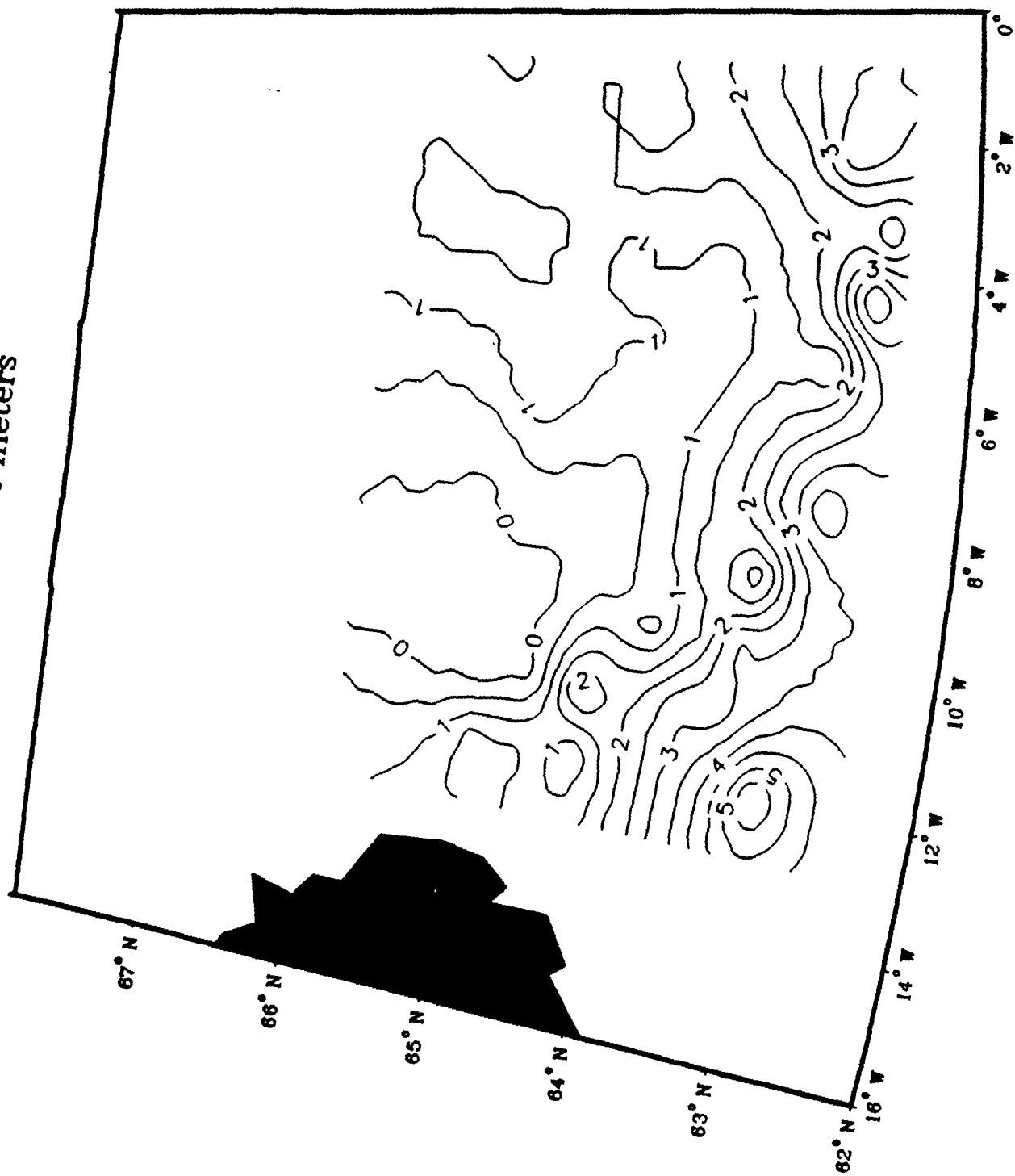
Temperature
22 May 1987
200 meters



Temperature
22 May 1987
300 meters



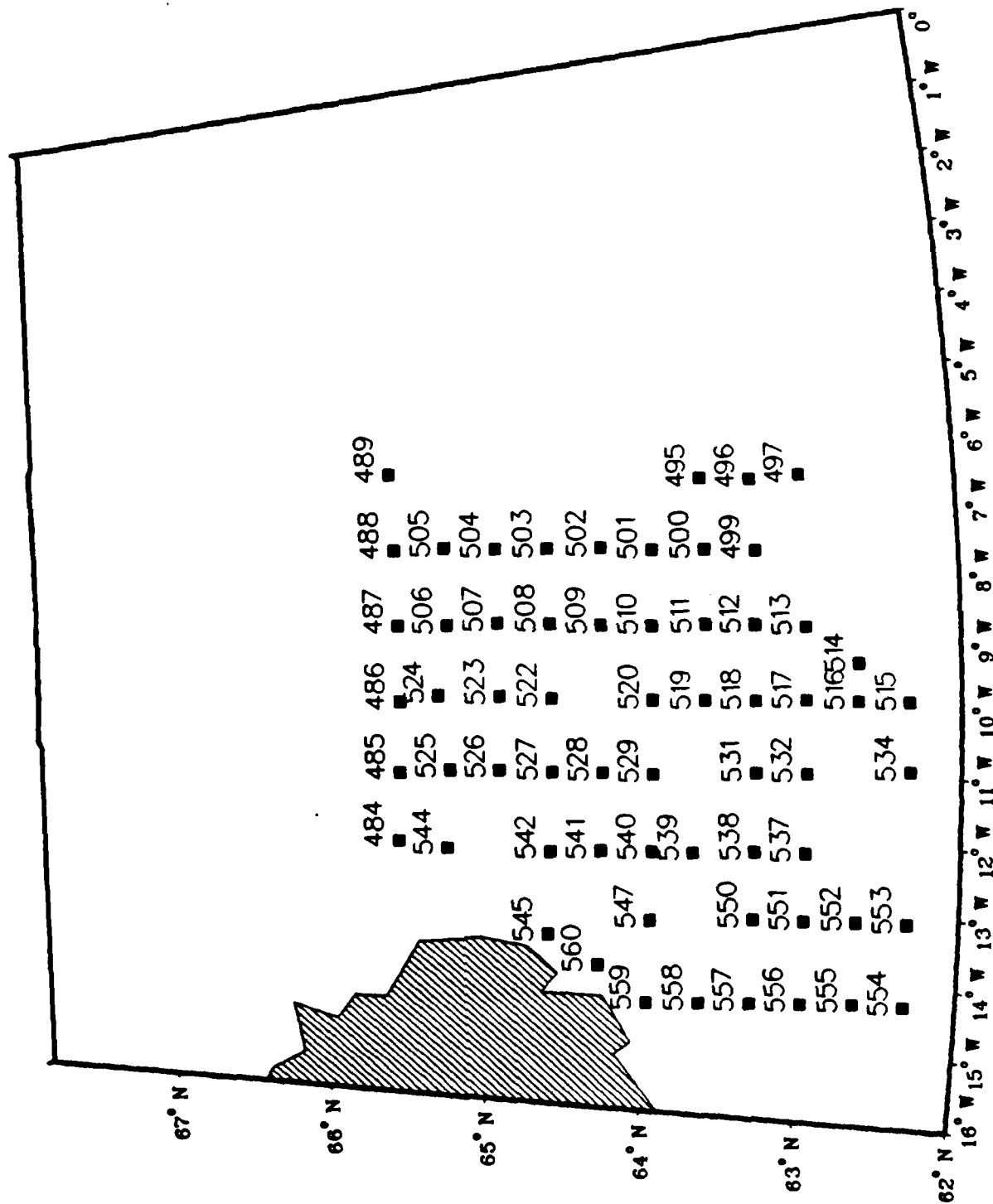
Temperature
22 May 1987
400 meters



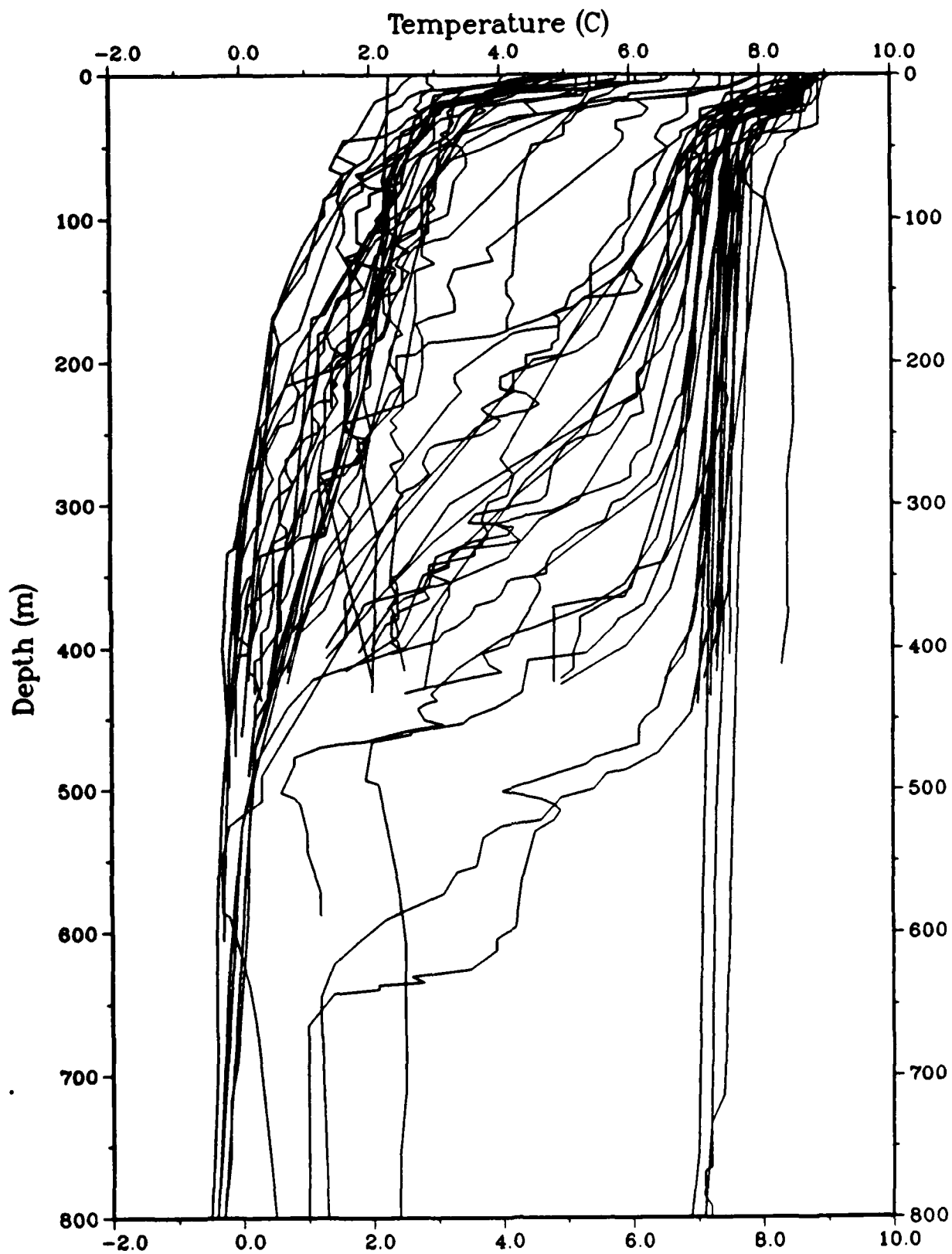
**Iceland-Faeroe Frontal Zone
Survey #4**

26 May 1987

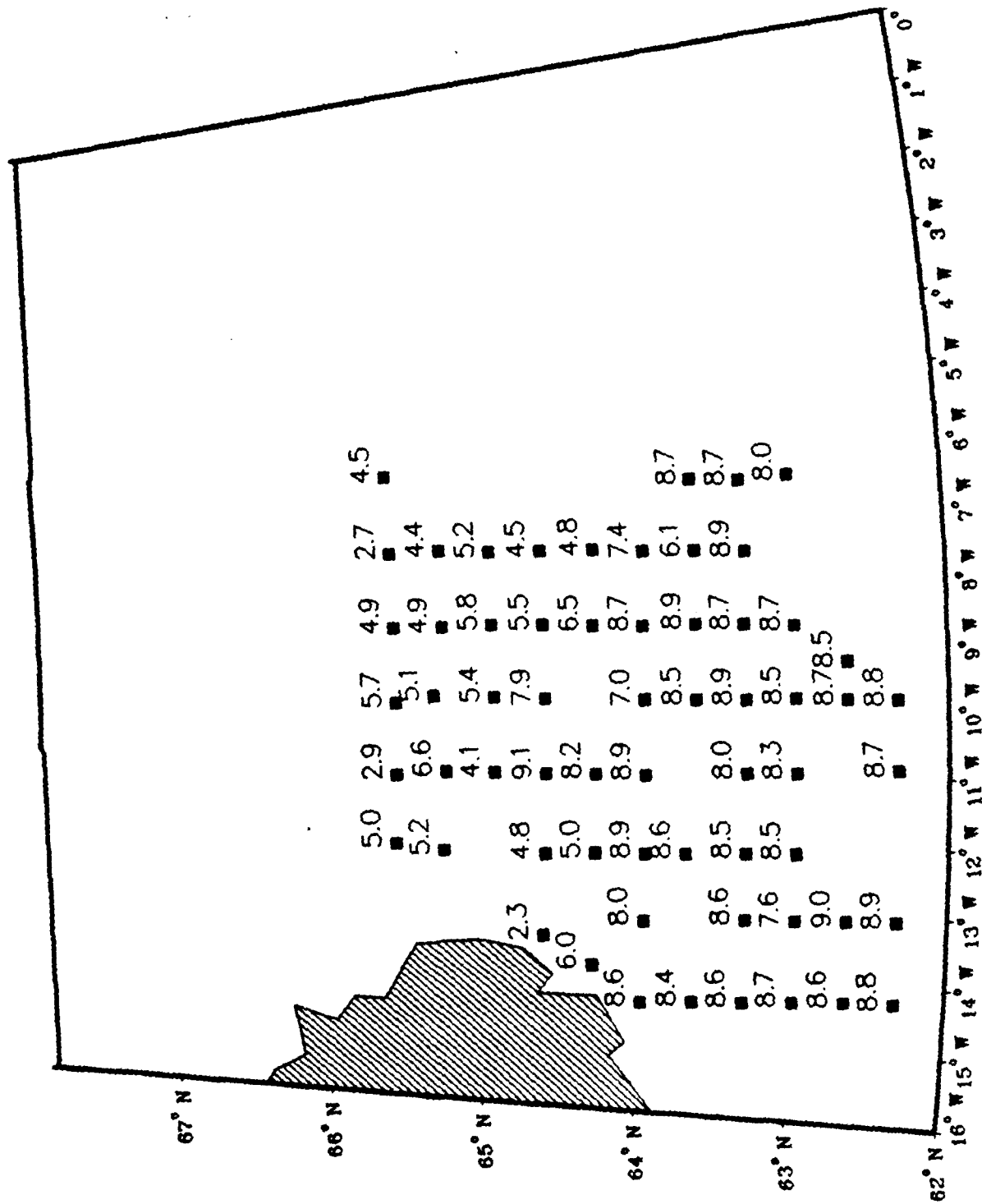
26 May 1987 AXBT Stations



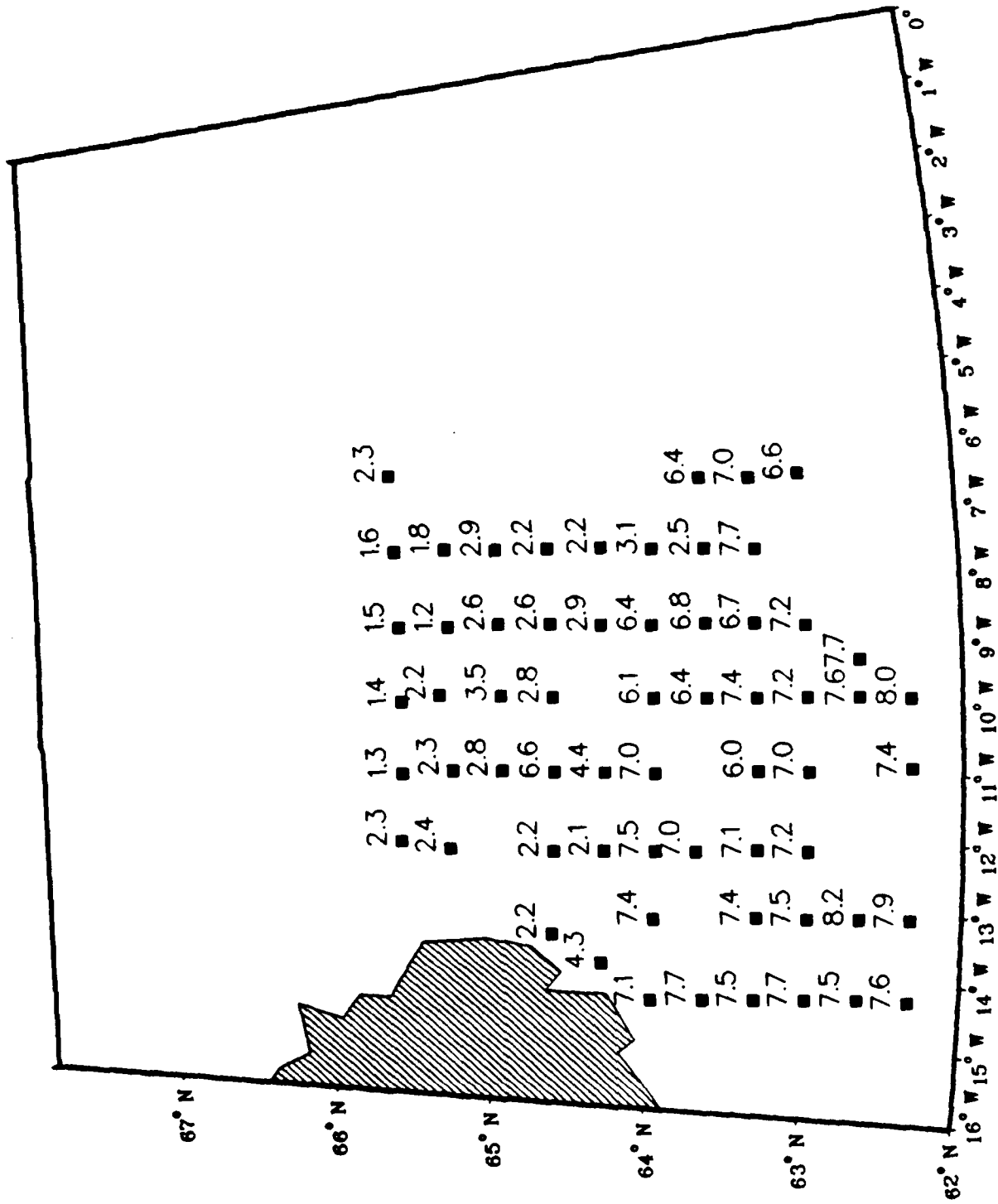
26 May 1987



26 May 1987
0 meters

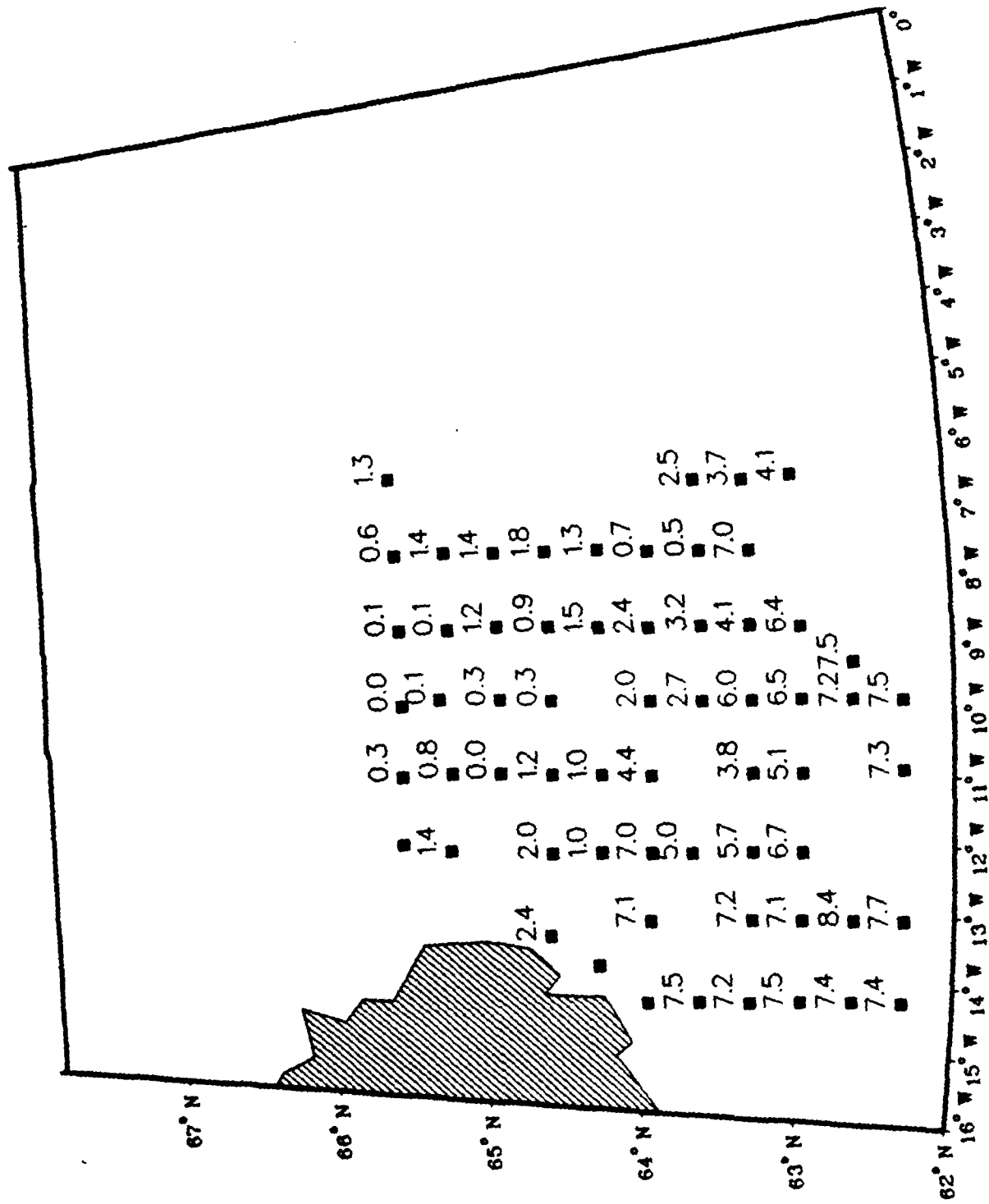


26 May 1987
100 meters



Map of the western North Atlantic showing bathymetry and station data for the 1970-71 cruise. The map covers 62°N to 67°N latitude and 0°W to 16°W longitude. Bathymetry is indicated by contour lines and shaded areas representing depths greater than 1000m. Station data points are marked with numbers and small squares, showing values ranging from 0.4 to 7.8. A shaded area in the upper left represents the continental shelf and slope.

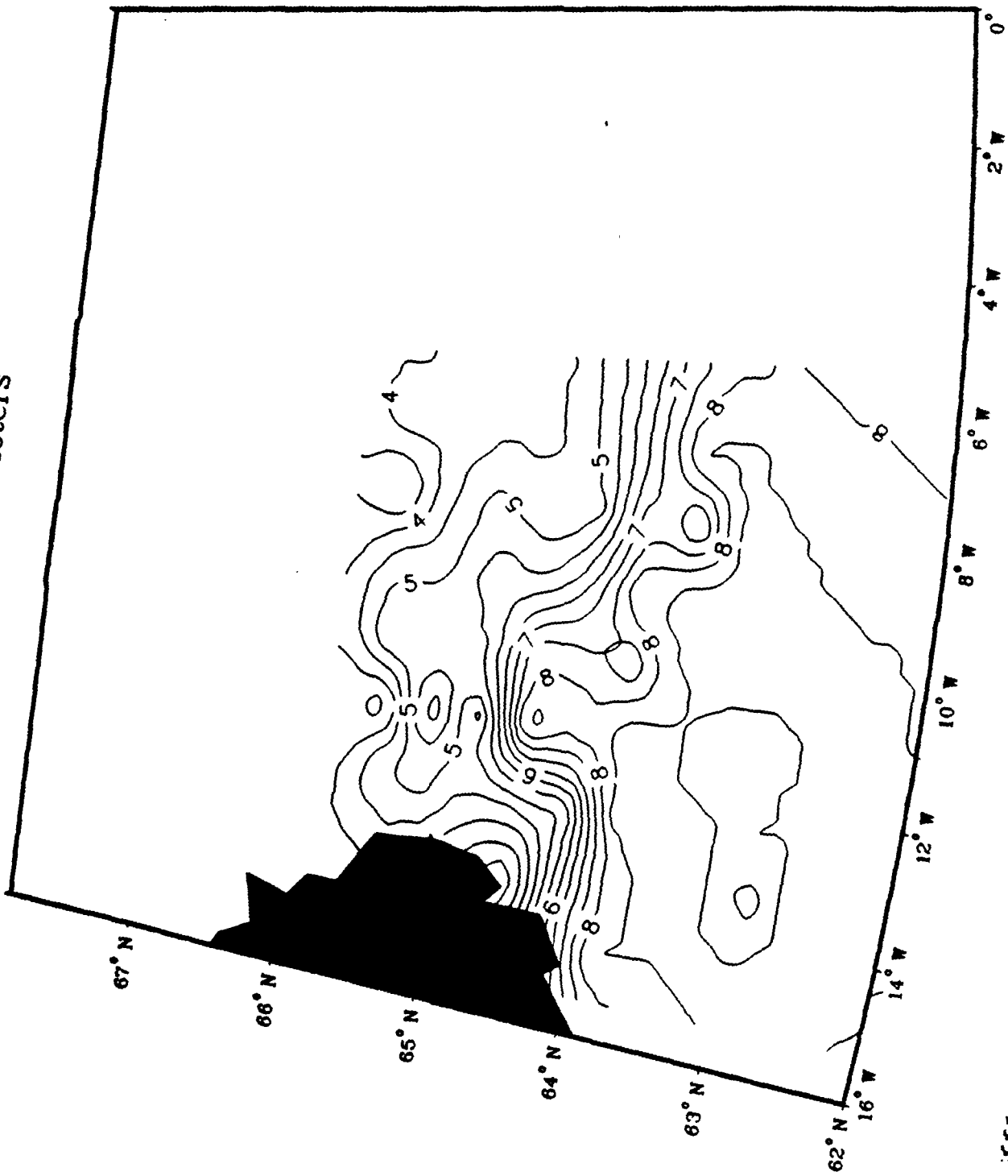
26 May 1987
300 meters



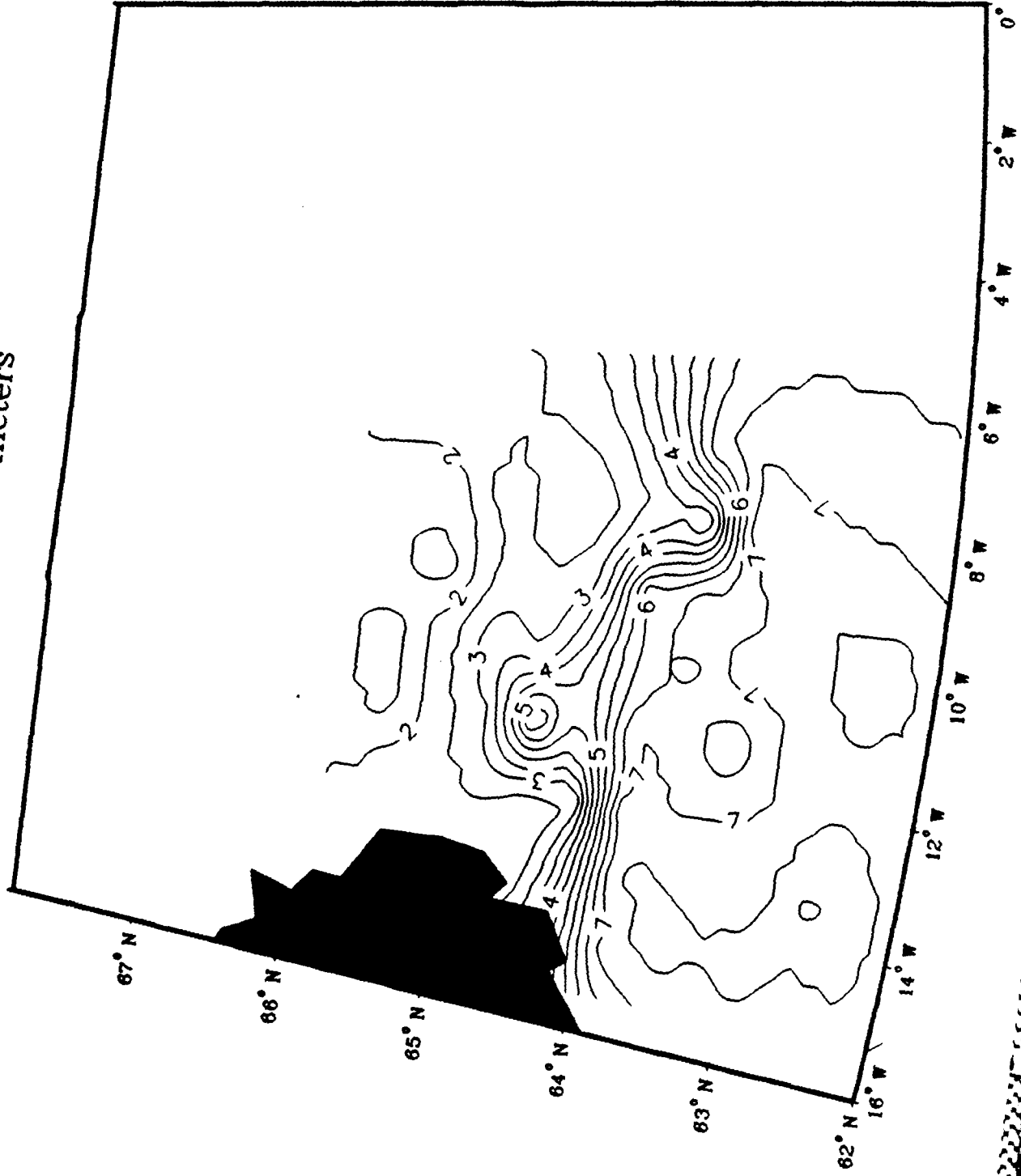
26 May 1987 300 meters

[illegible]

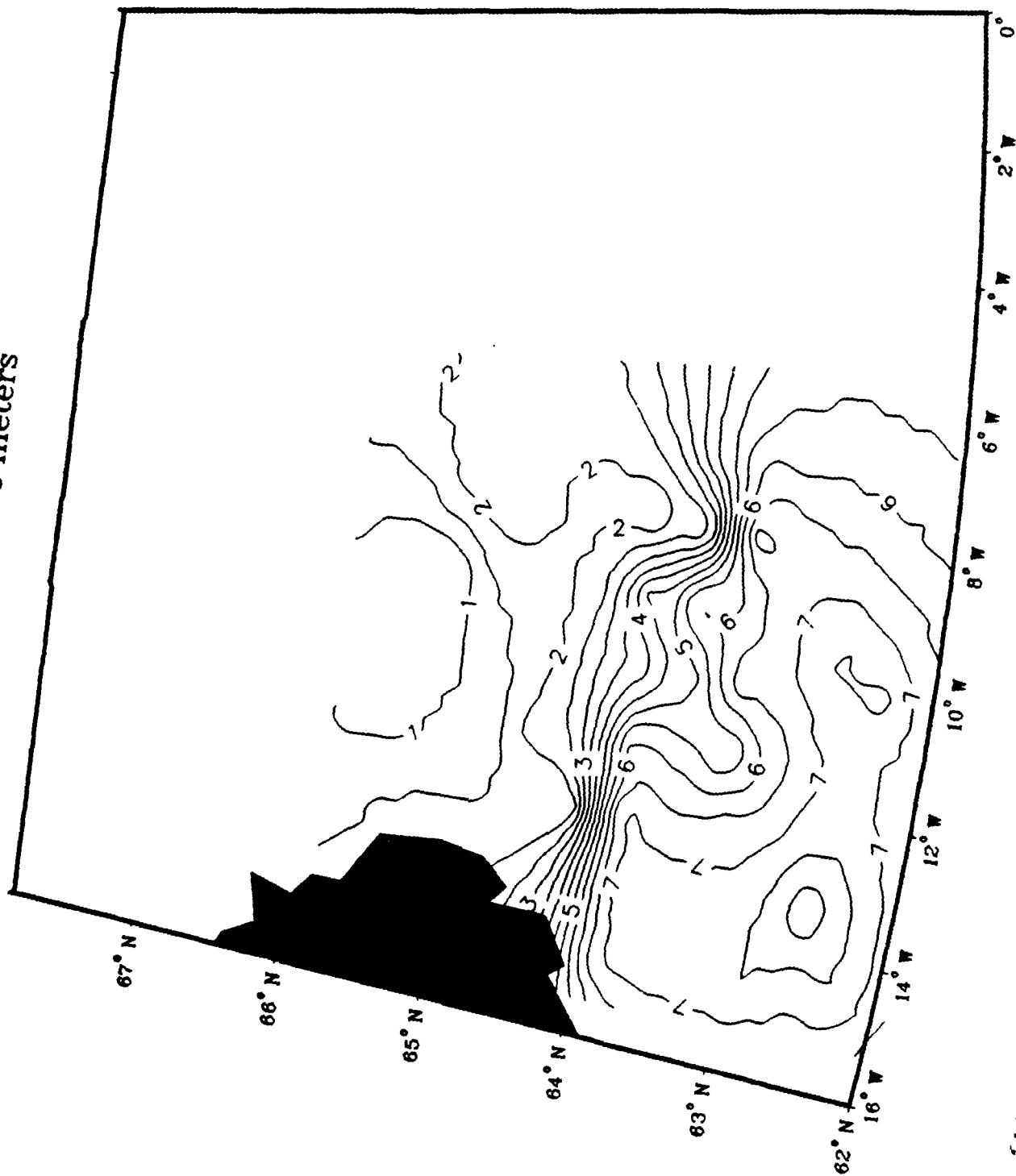
Temperature
26 May 1987
0 meters



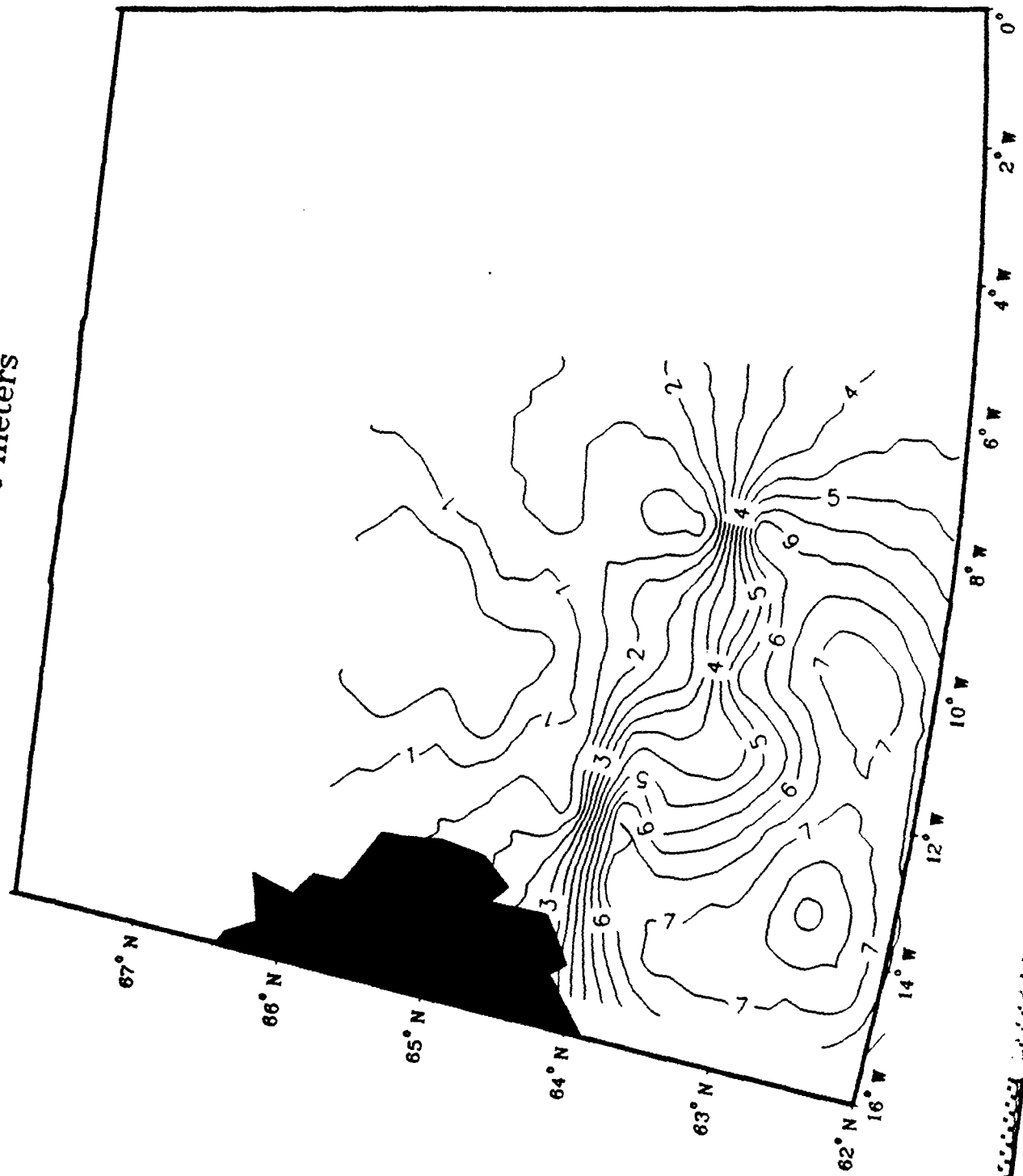
Temperature
26 May 1987
100 meters



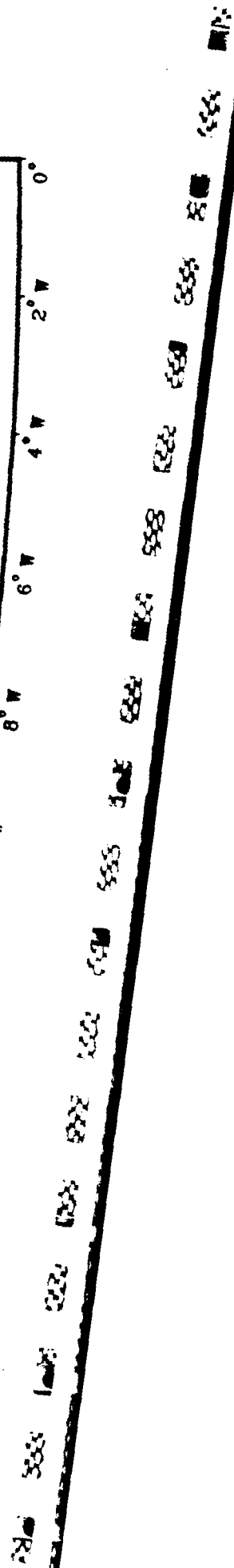
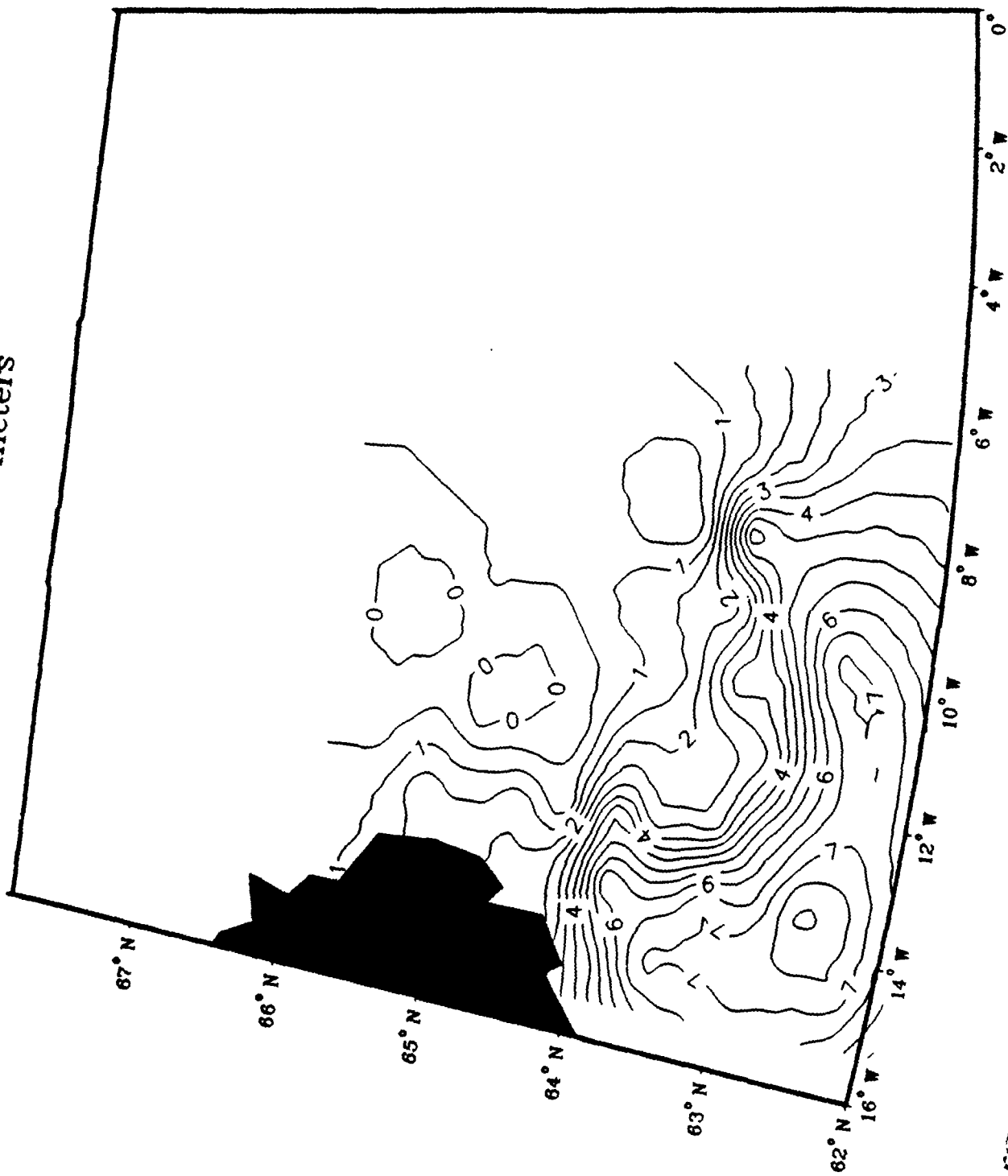
Temperature
26 May 1987
200 meters

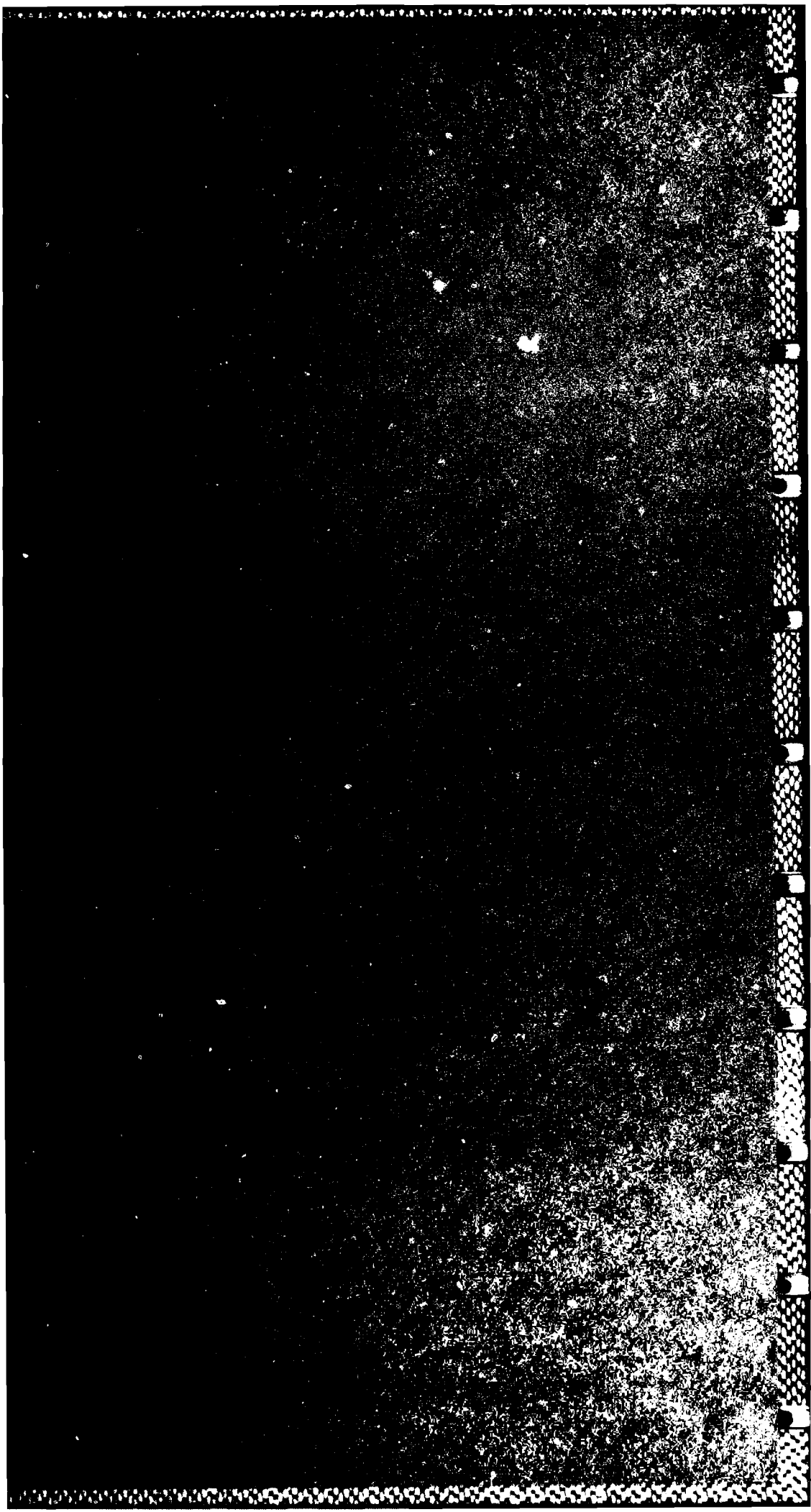


Temperature
26 May 1987
300 meters



Temperature
26 May 1987
400 meters

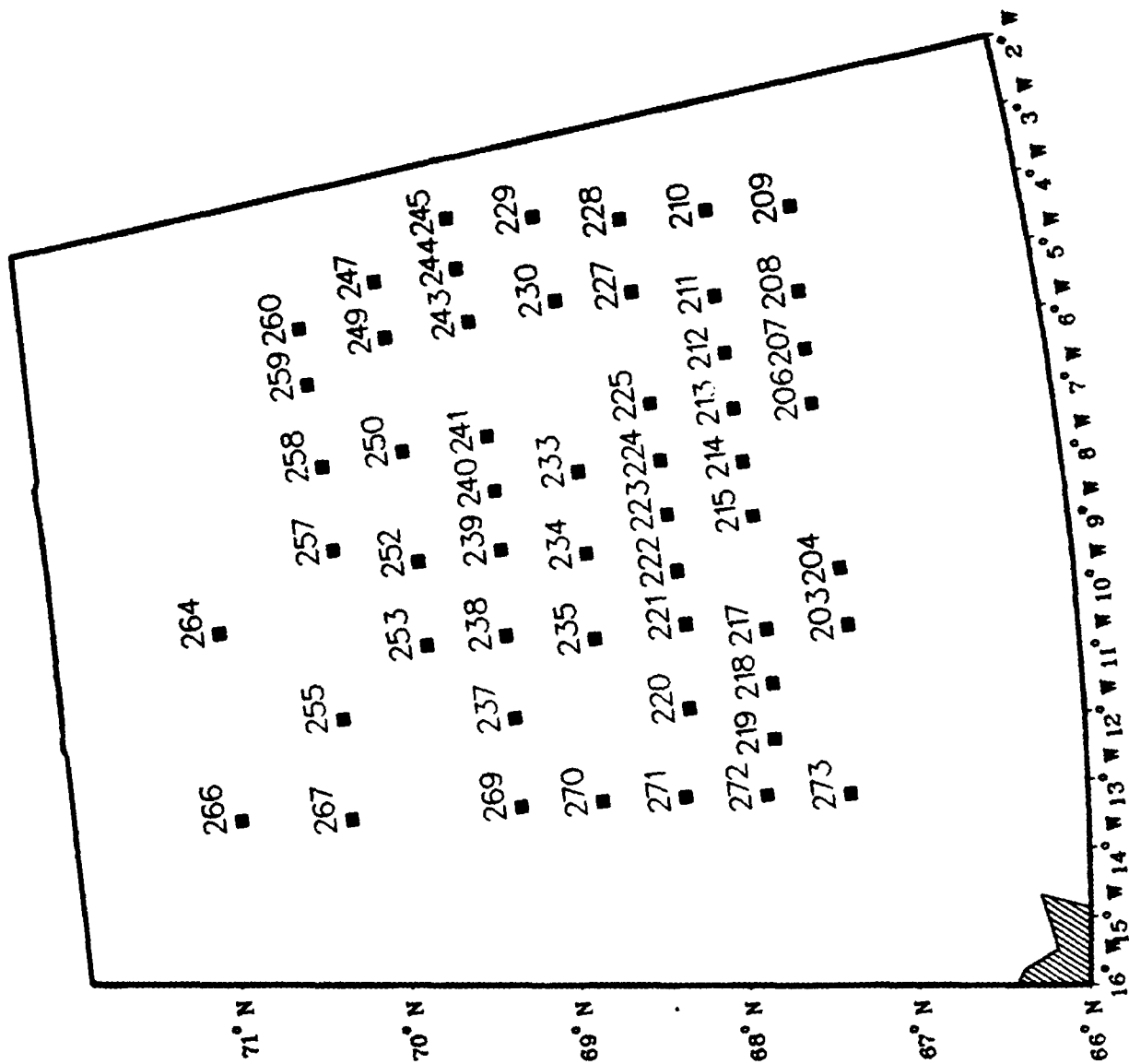




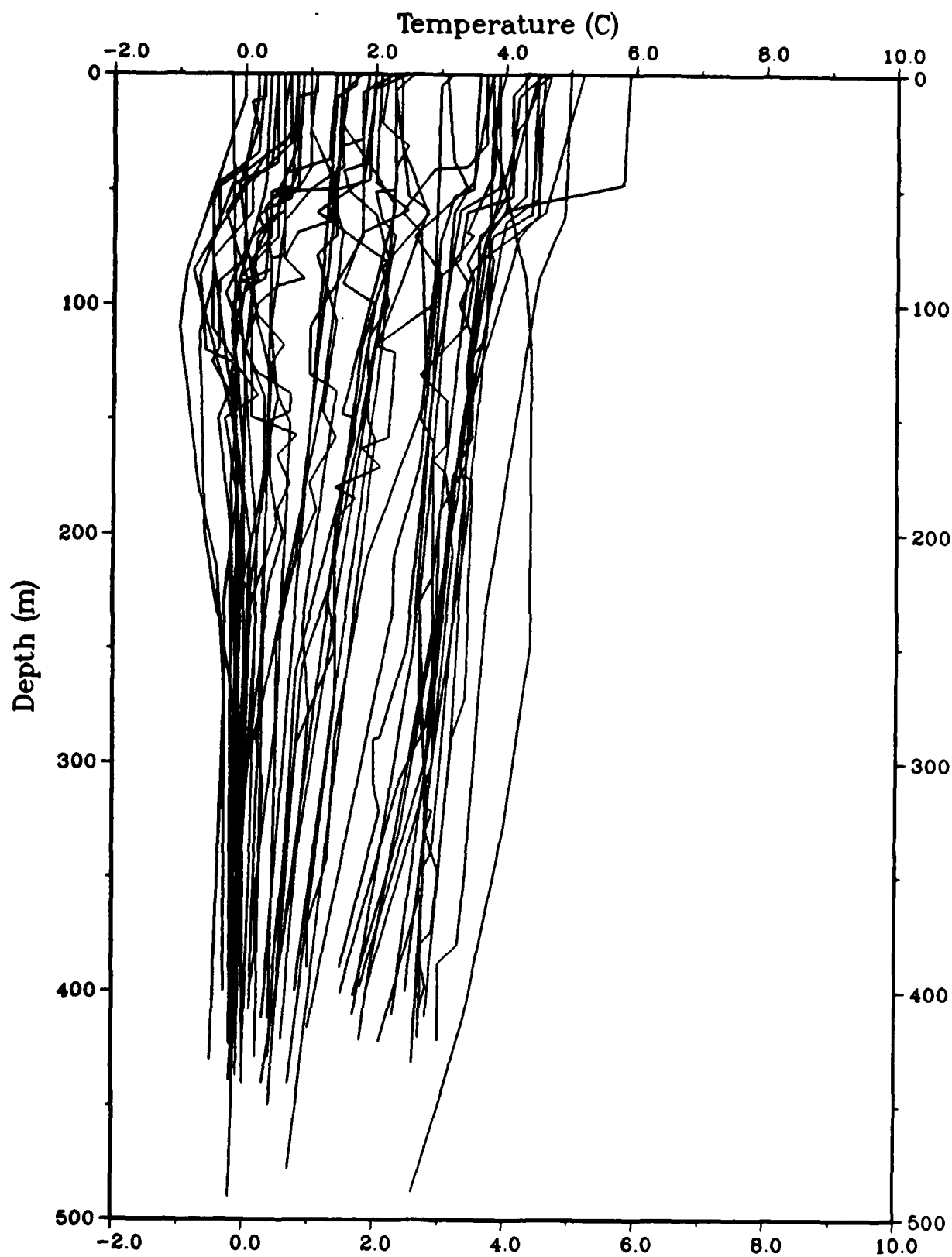
Jan Mayen Frontal Zone Survey

20 May 1987

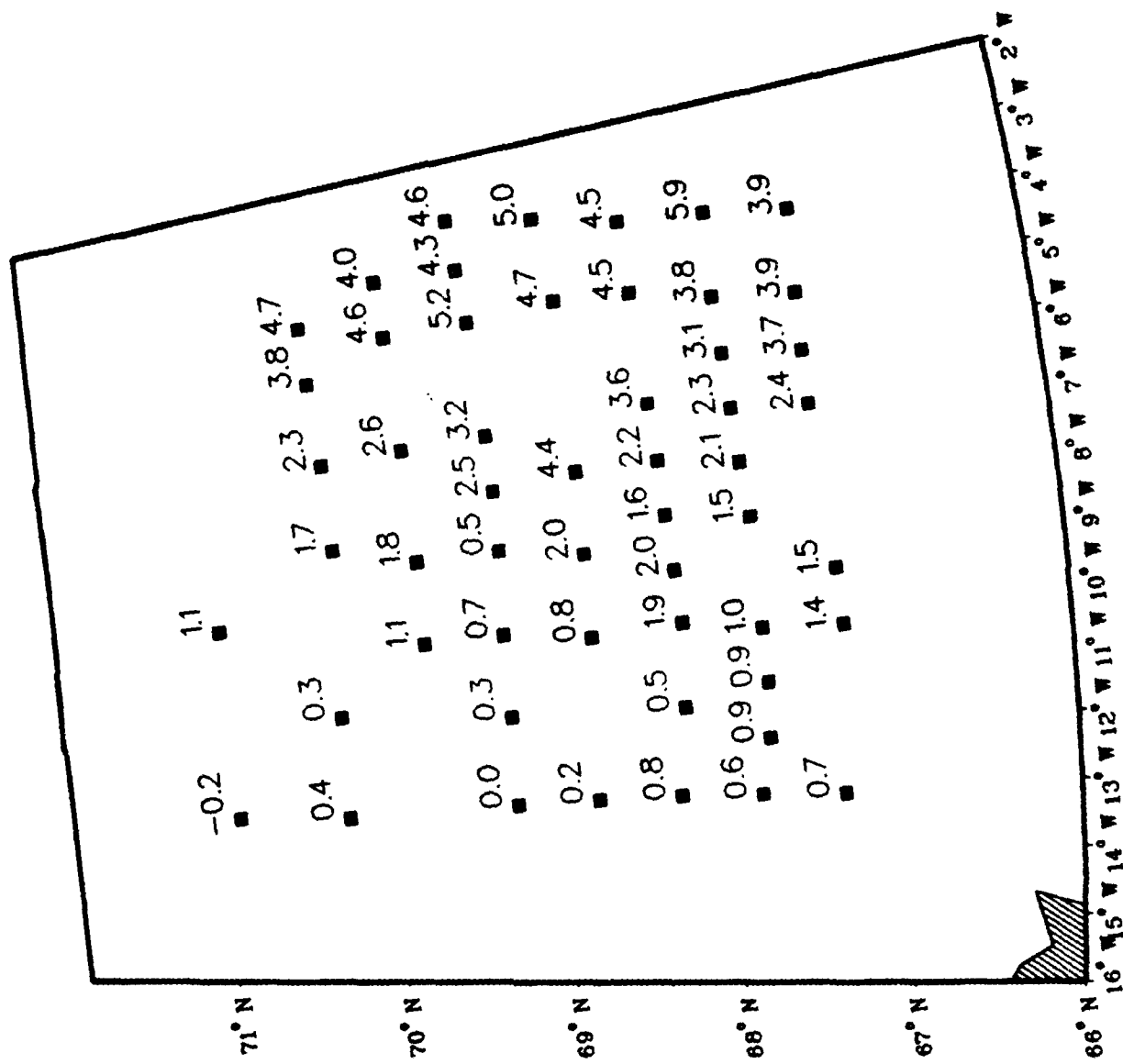
20 May 1987 AXBT Stations



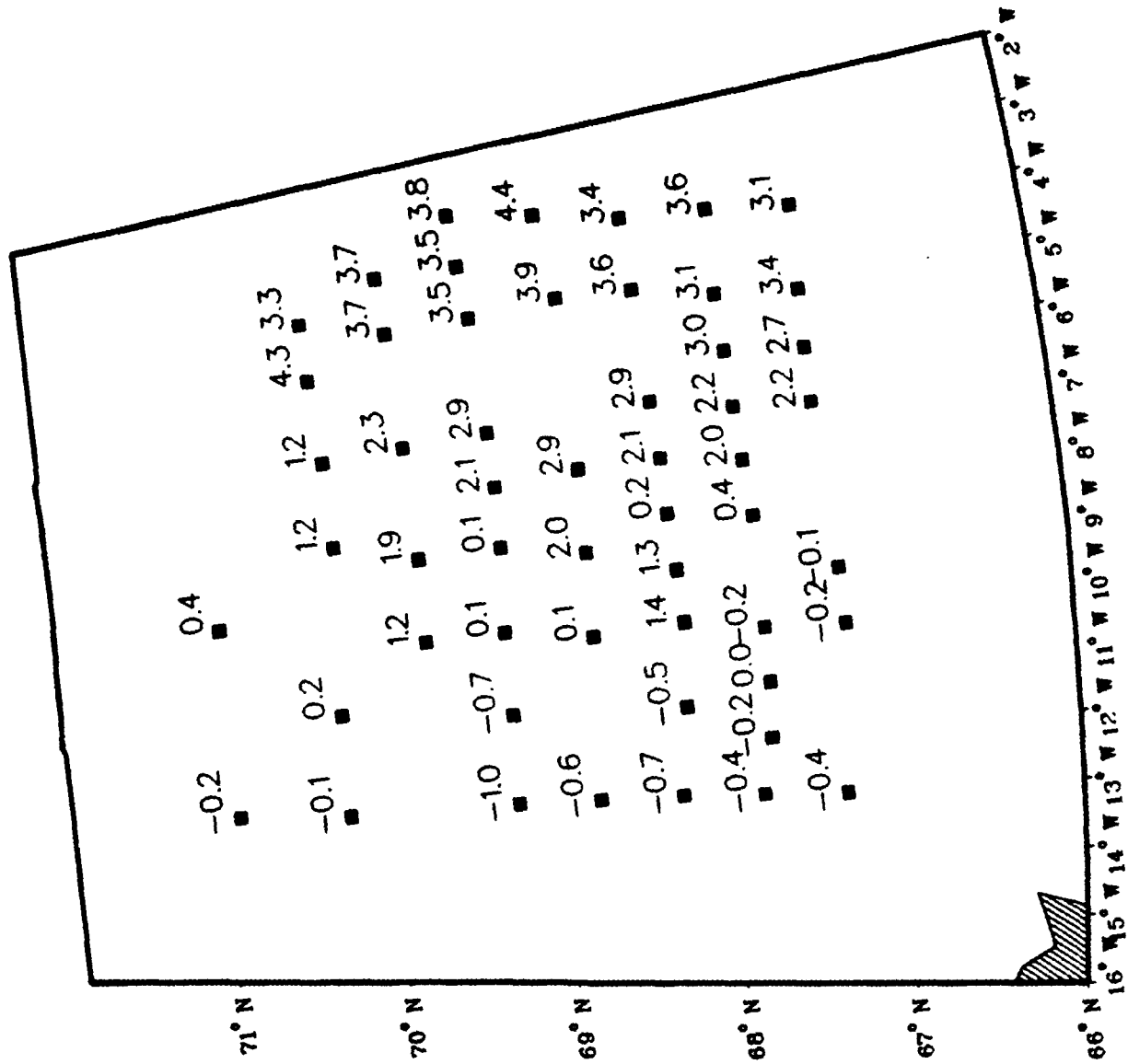
20 May 1987



20 May 1987
0 meters

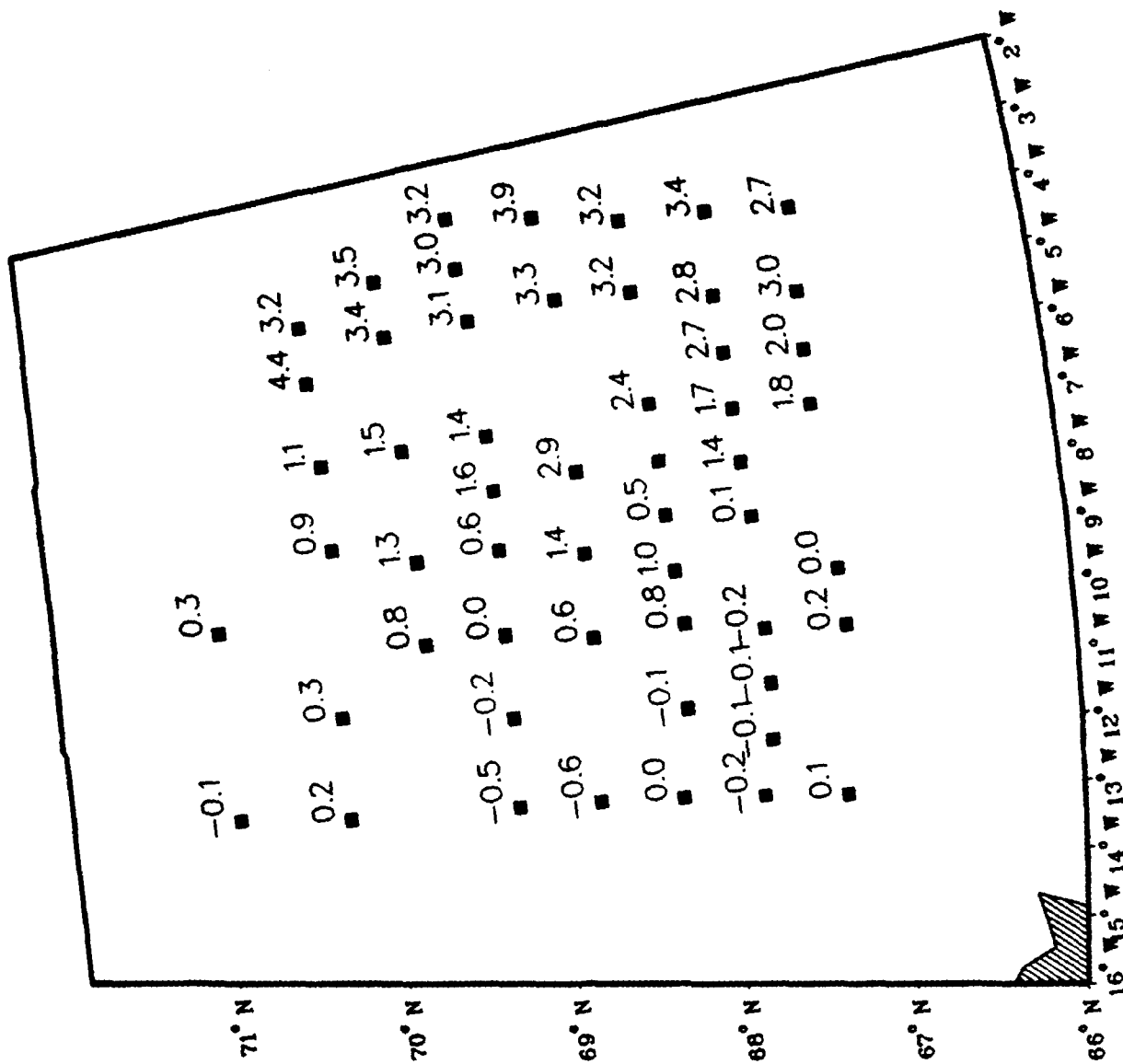


20 May 1987
100 meters



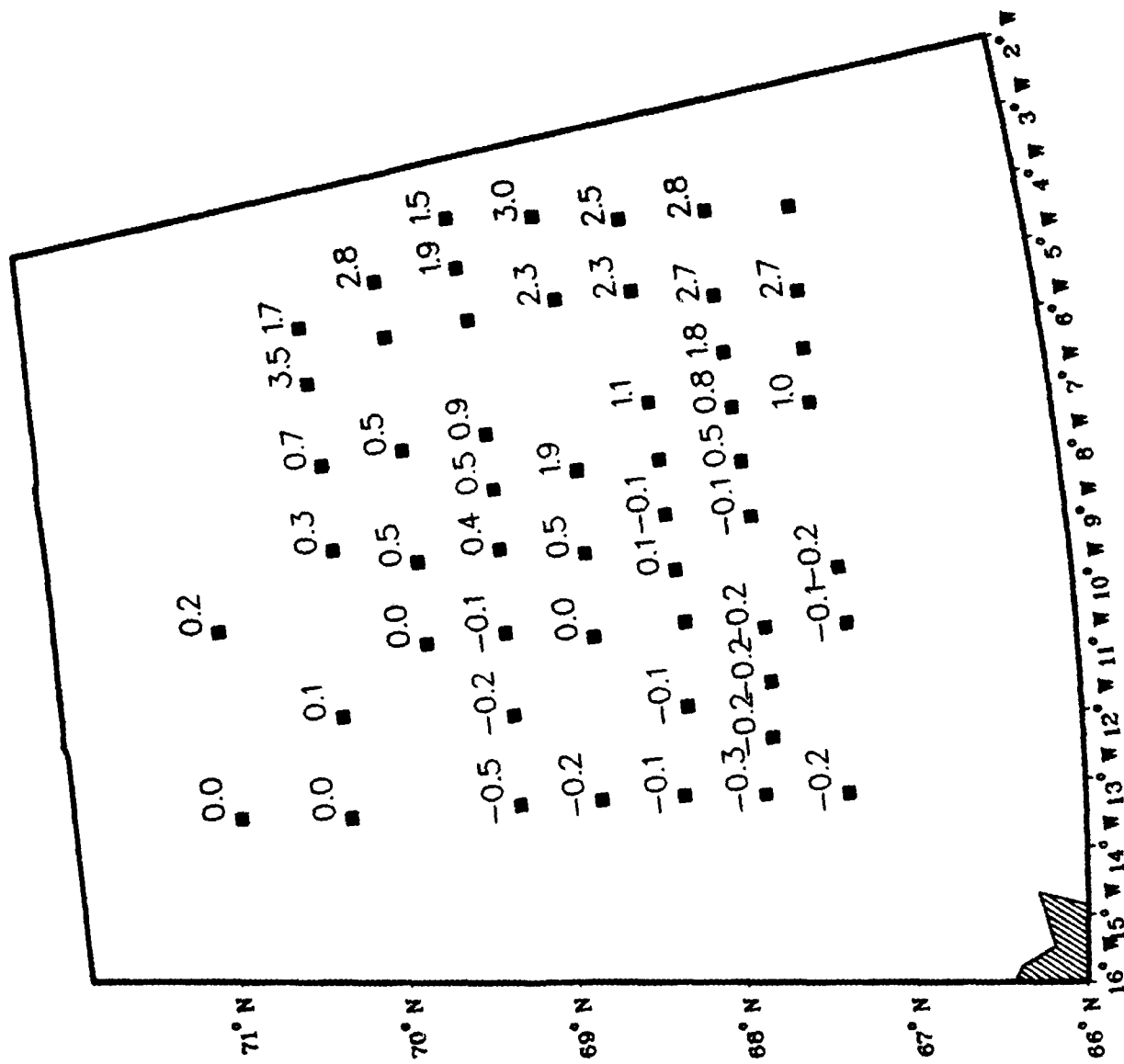
1987

20 May 1987
200 meters

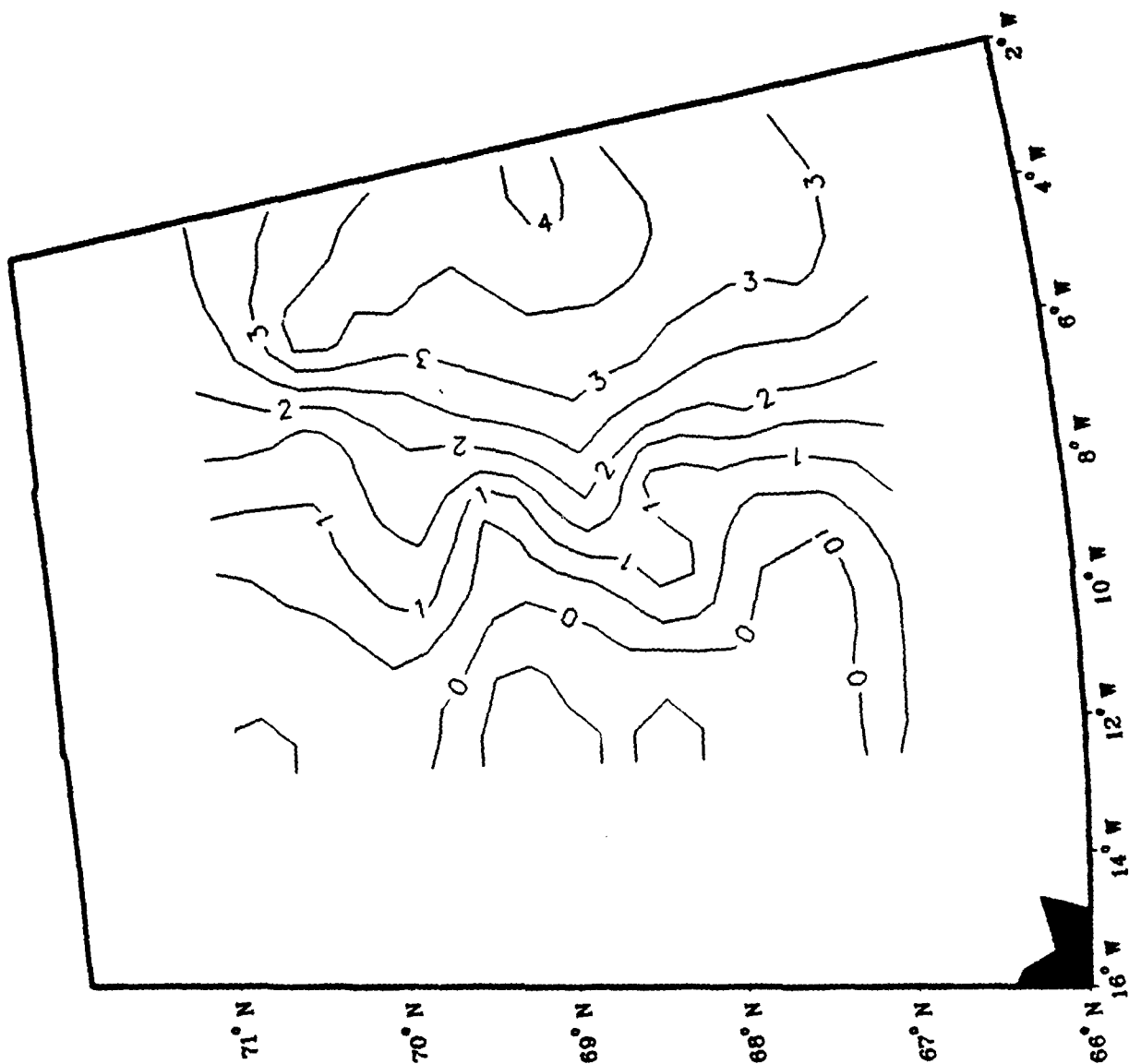


Map of the study area showing sampling stations and depth profiles. The map covers the region from 66°N to 71°N latitude and 16°W to 2°W longitude. Depth profiles are shown for stations 1 through 10, with values ranging from -0.3 to 4.1. A scale bar indicates 100 km.

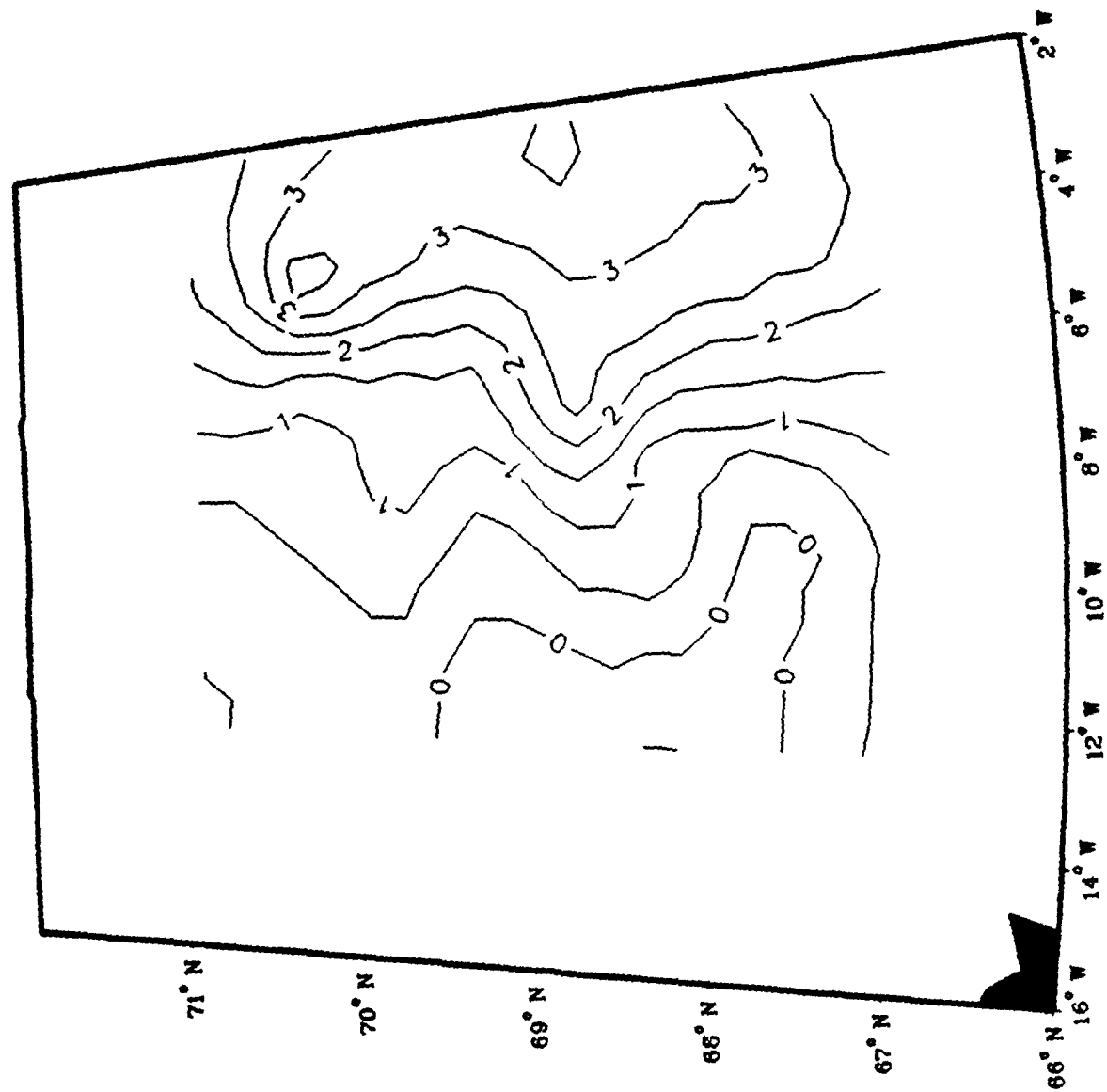
20 May 1987
400 meters



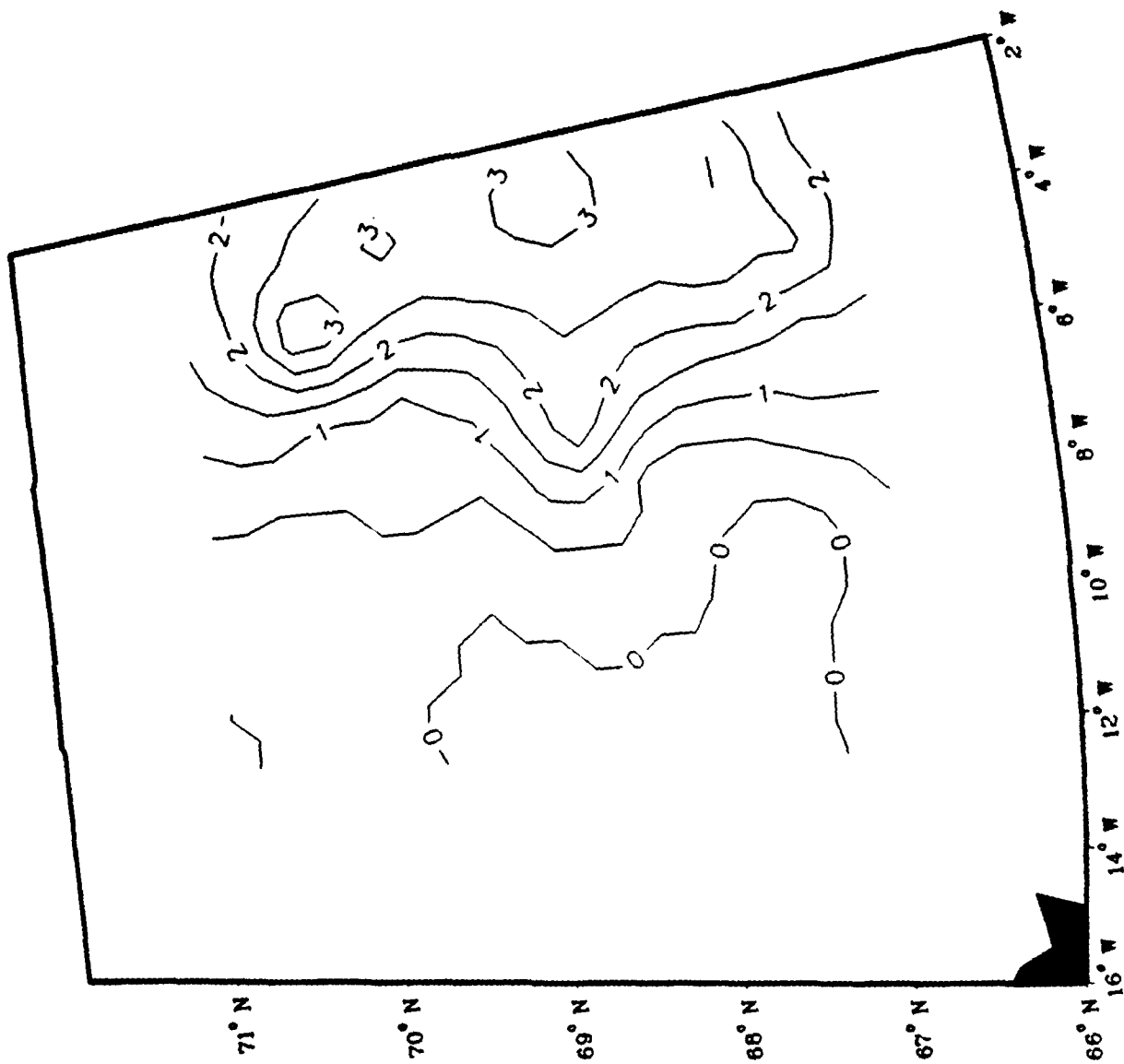
Temperature
20 May 1987
100 meters



Temperature
20 May 1987
200 meters



Temperature
20 May 1987
300 meters

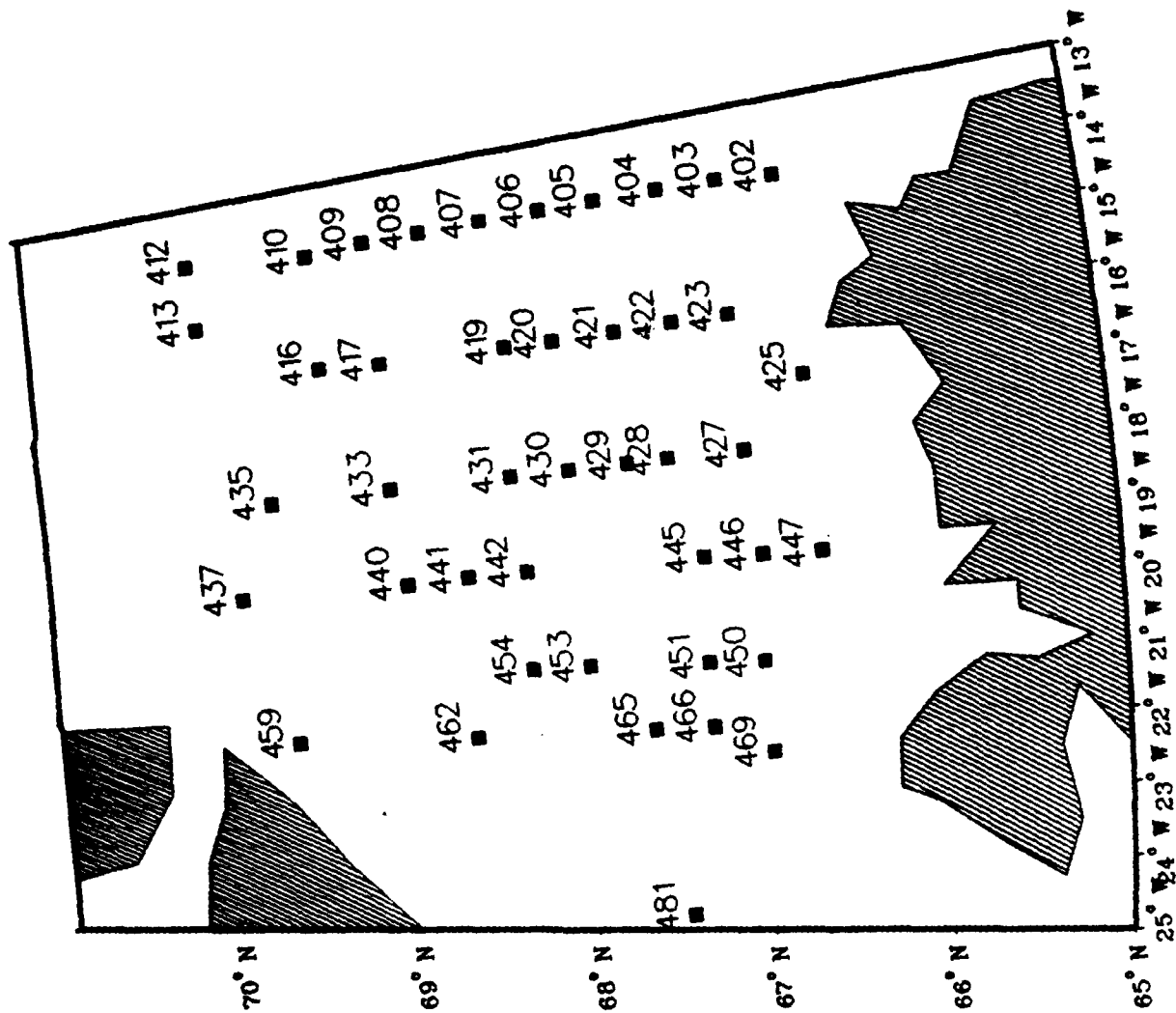


37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021 1022 1023 1024 1025 1026 1027 1028 1029 1030 1031 1032 1033 1034 1035 1036 1037 1038 1039 1040 1041 1042 1043 1044 1045 1046 1047 1048 1049 1050 1051 1052 1053 1054 1055 1056 1057 1058 1059 10

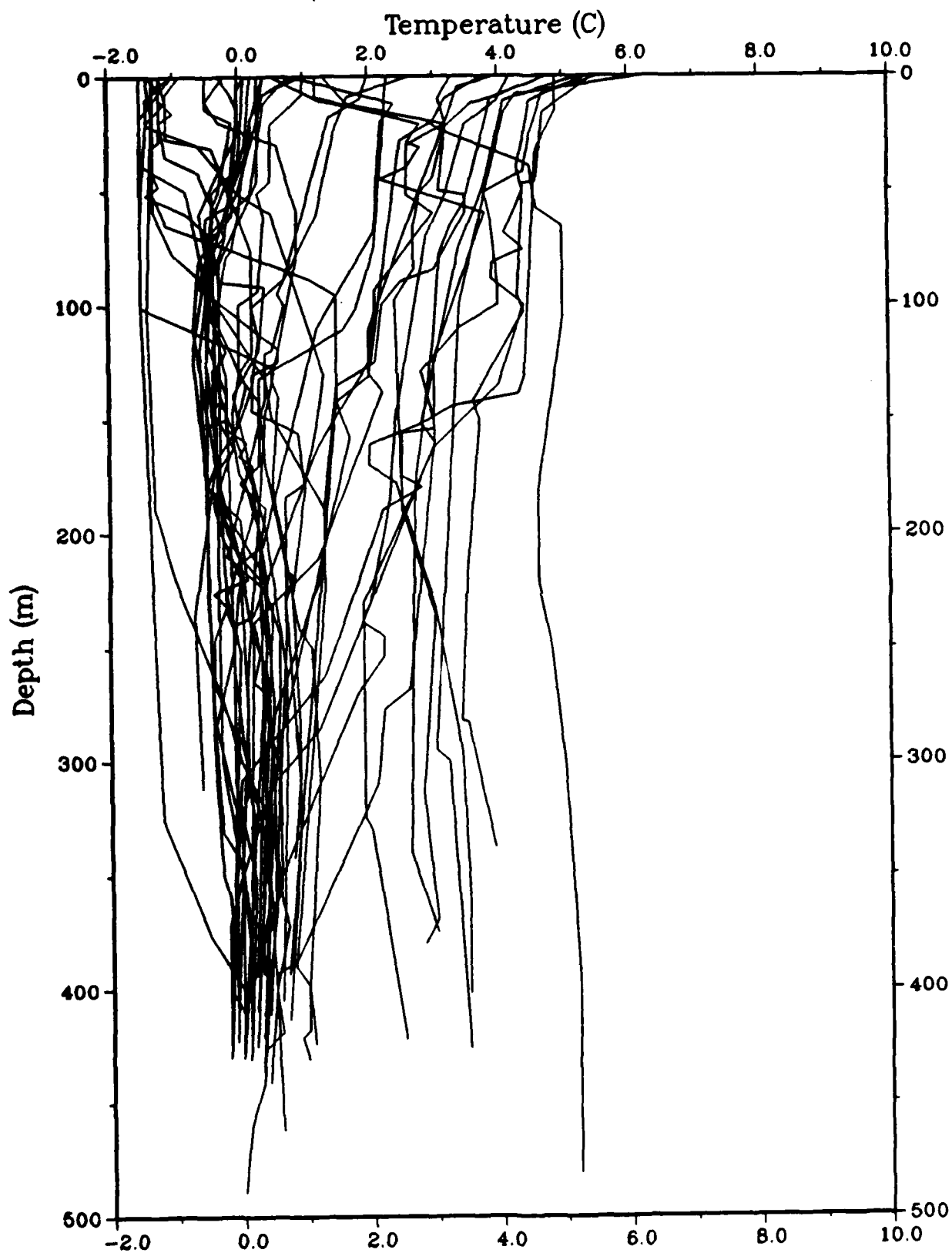
Island Sea Survey

25 May 1967

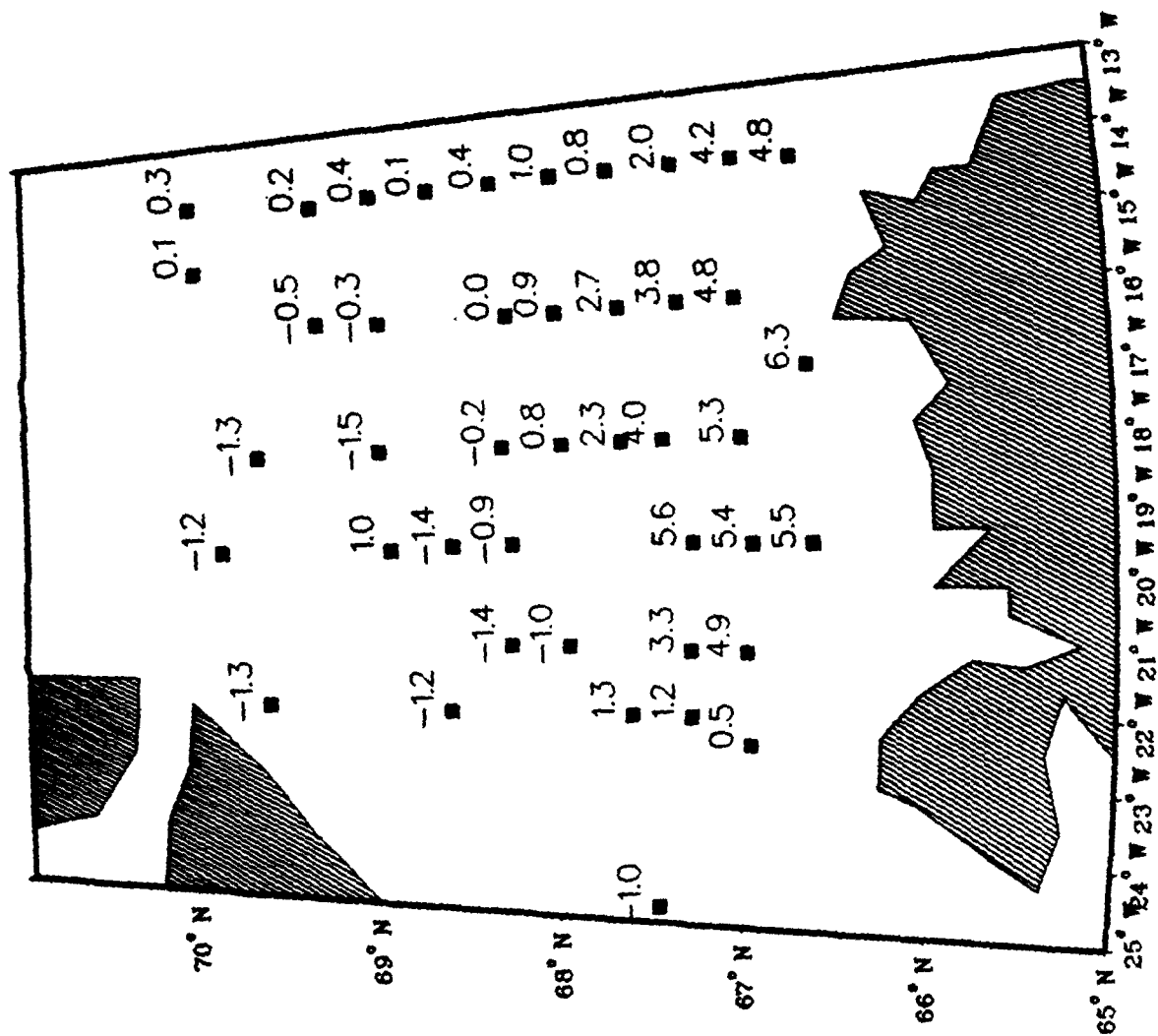
24 May 1987 AXBT Stations



24 May 1987



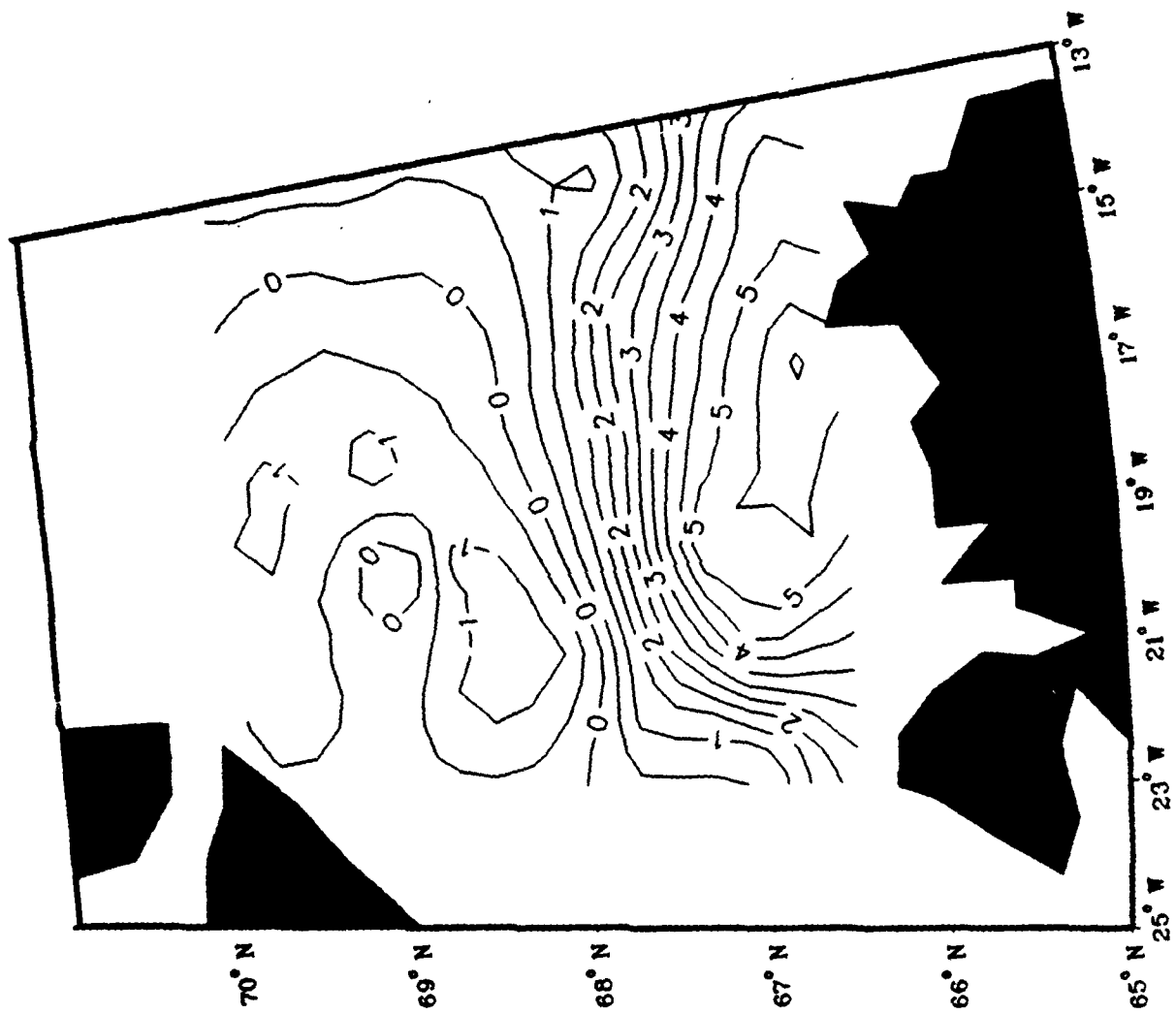
24 May 1987
0 meters



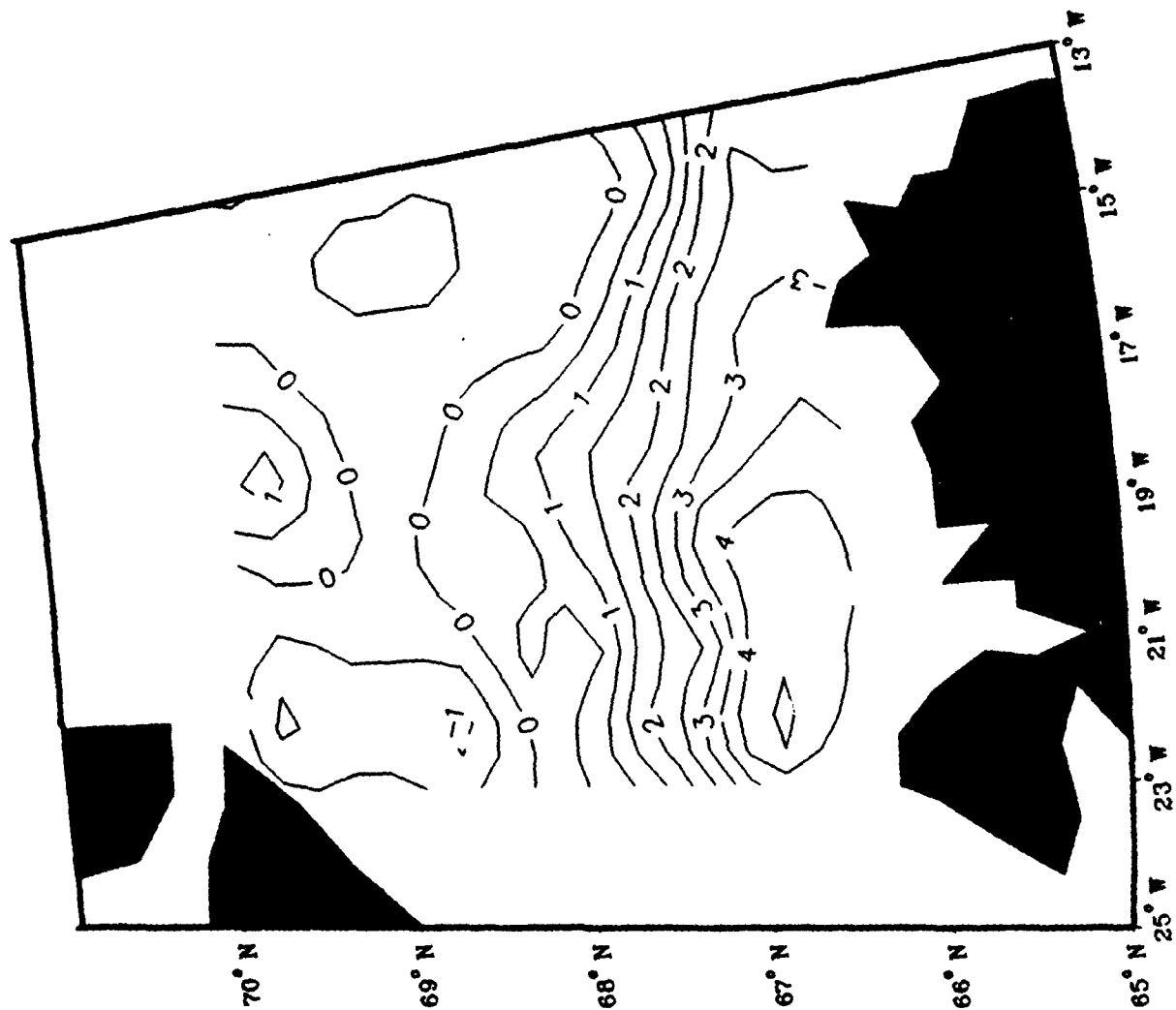
Map of the North Atlantic Ocean showing SST anomalies. The map covers latitudes from 65°N to 70°N and longitudes from 25°W to 13°W. Shaded areas represent landmasses (North America, Greenland, and Europe). Numerical values are plotted at various grid points, ranging from -1.4 to 3.6. The values show a general trend of increasing temperature anomalies from west to east and from south to north.

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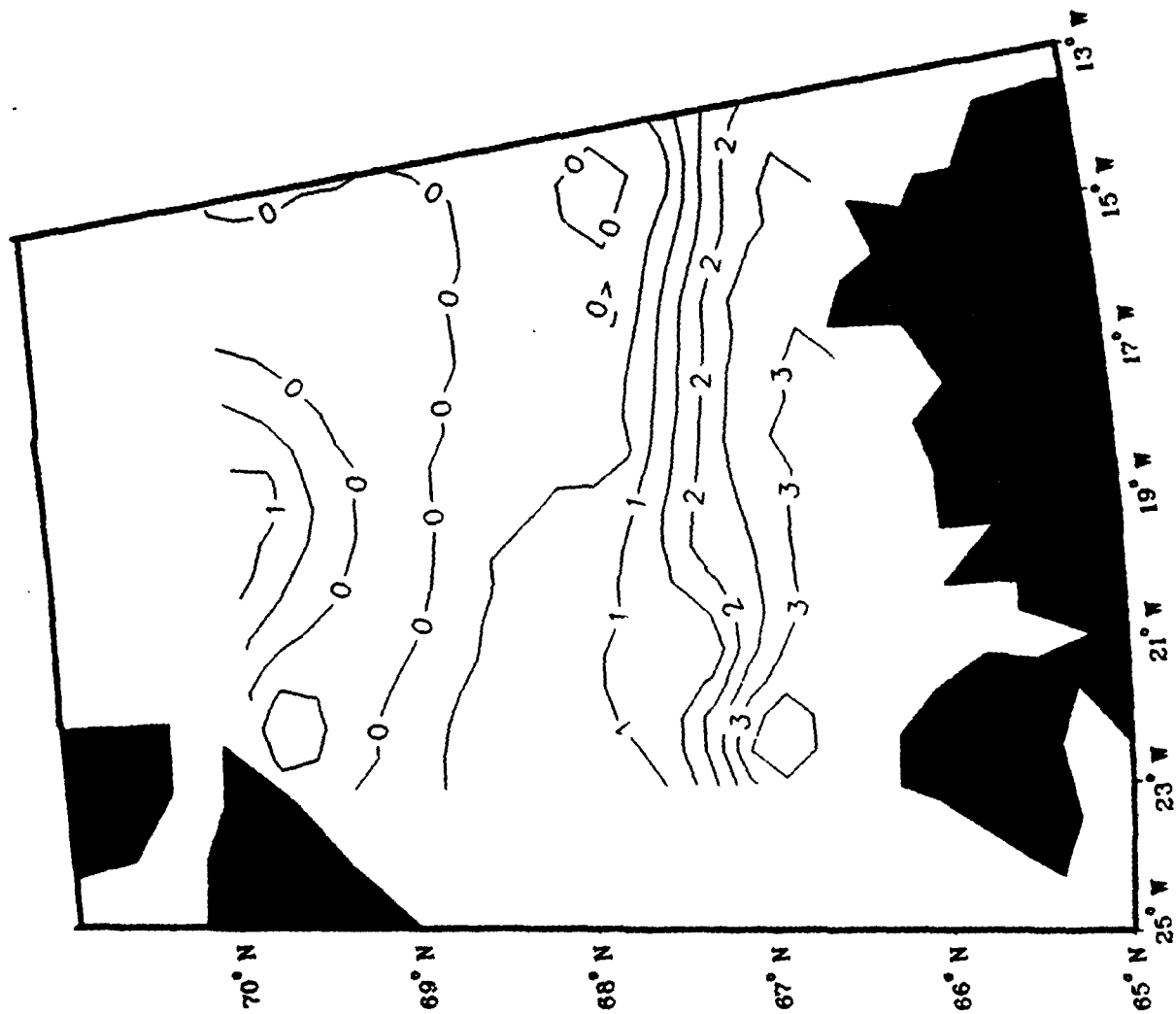
Temperature
24 May 1987
0 meters



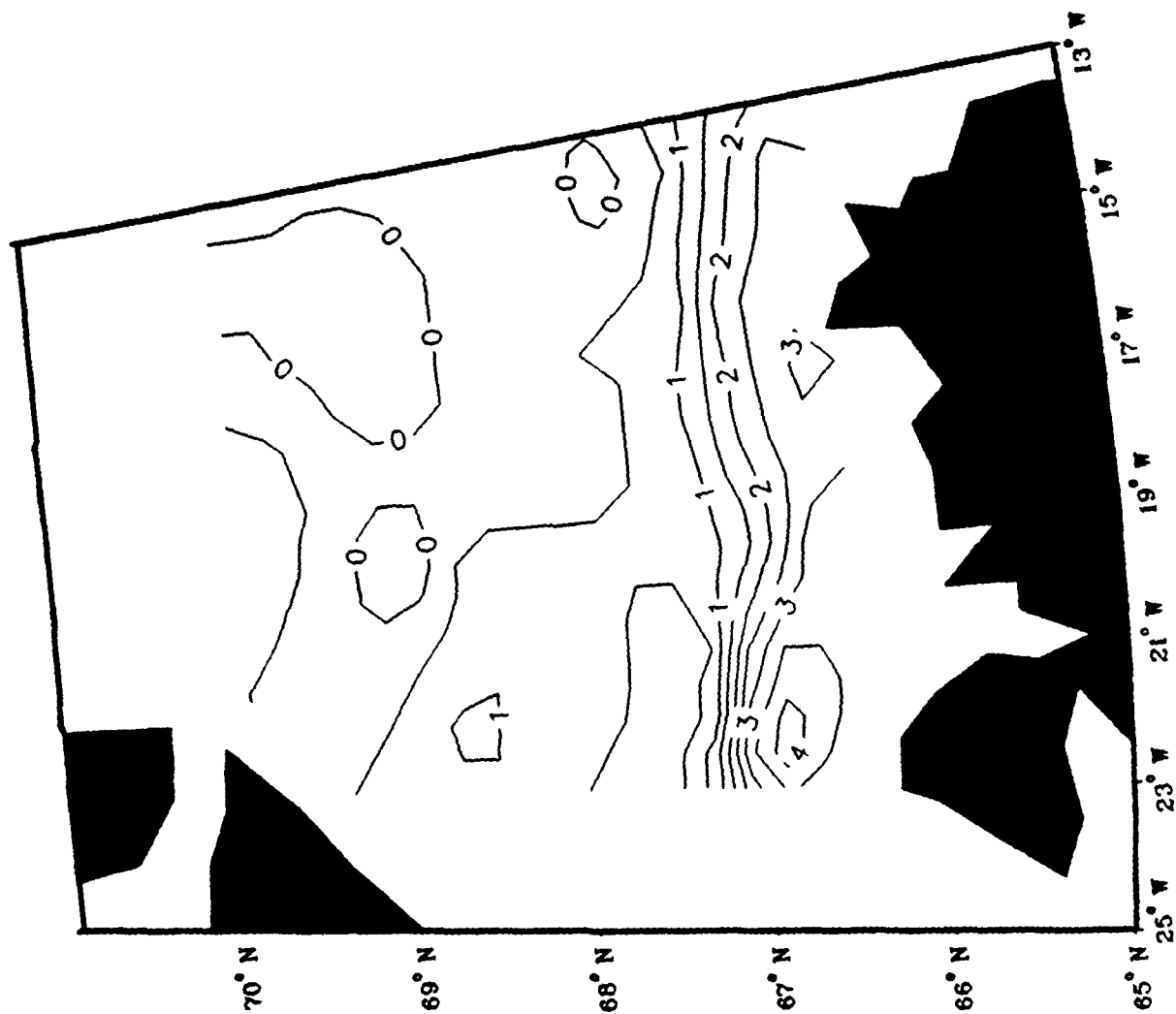
Temperature
24 May 1987
100 meters



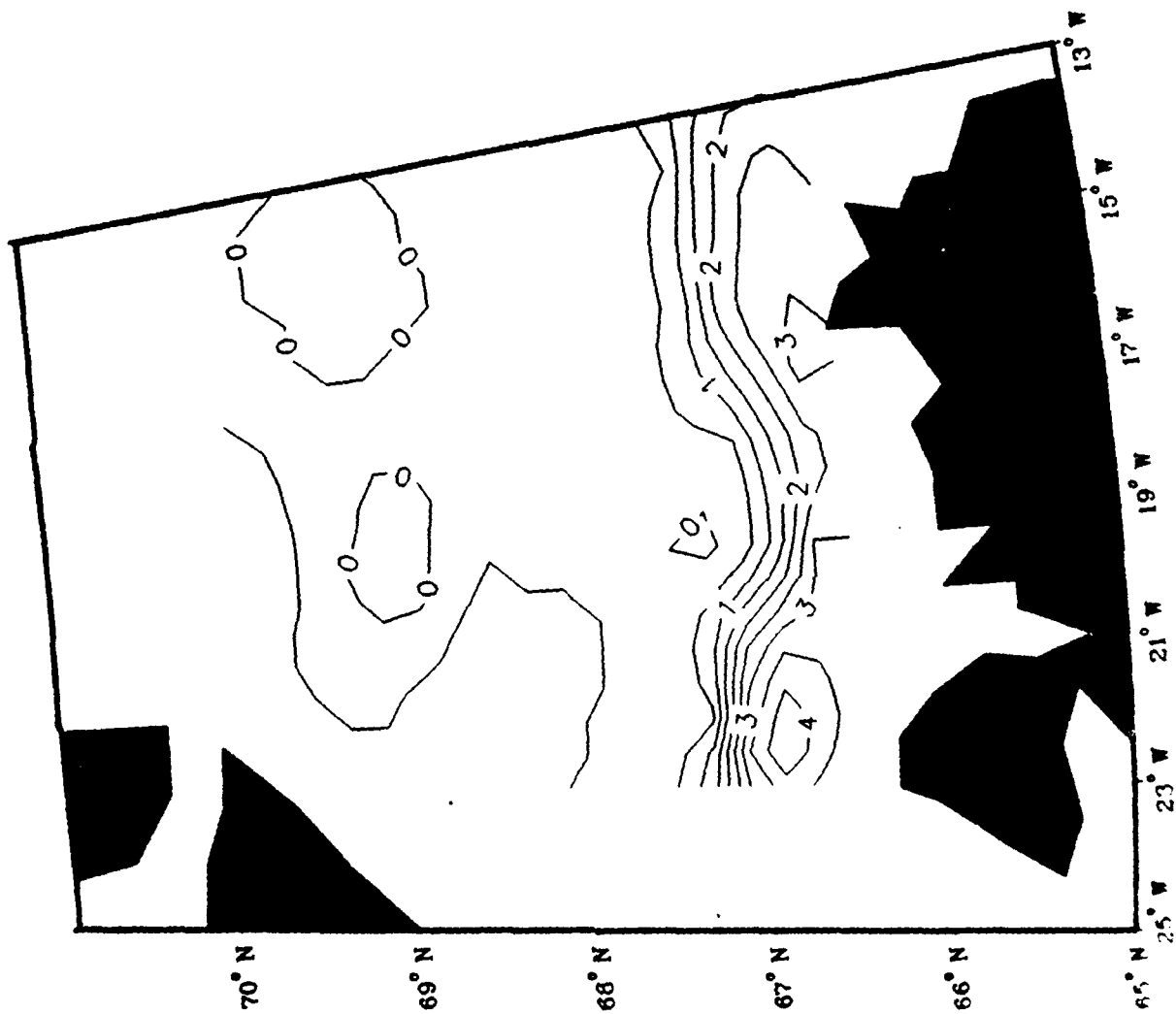
Temperature
24 May 1987
200 meters



Temperature
24 May 1987
300 meters



Temperature 24 May 1987 400 meters



NO-A191 961

ENVIRONMENTAL CONDITIONS IN THE NORWEGIAN-ICELAND SEAS
MAY 1987(U) NAVAL OCEAN RESEARCH AND DEVELOPMENT
ACTIVITY NSTL STATION HS J D BOYD ET AL. JUN 87

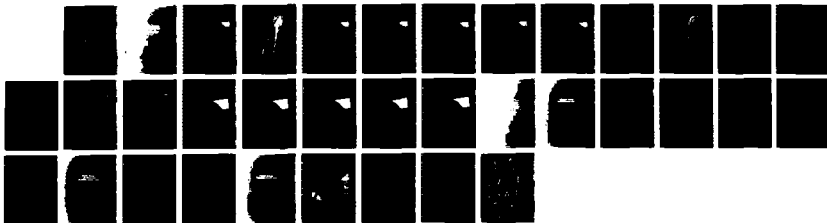
2/2

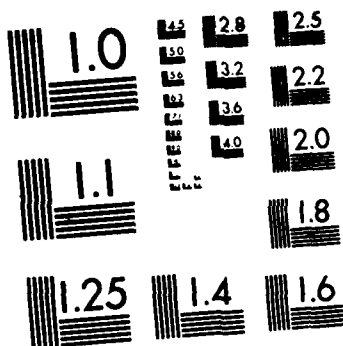
UNCLASSIFIED

NORDA-TN-341

F/G 8/3

NL

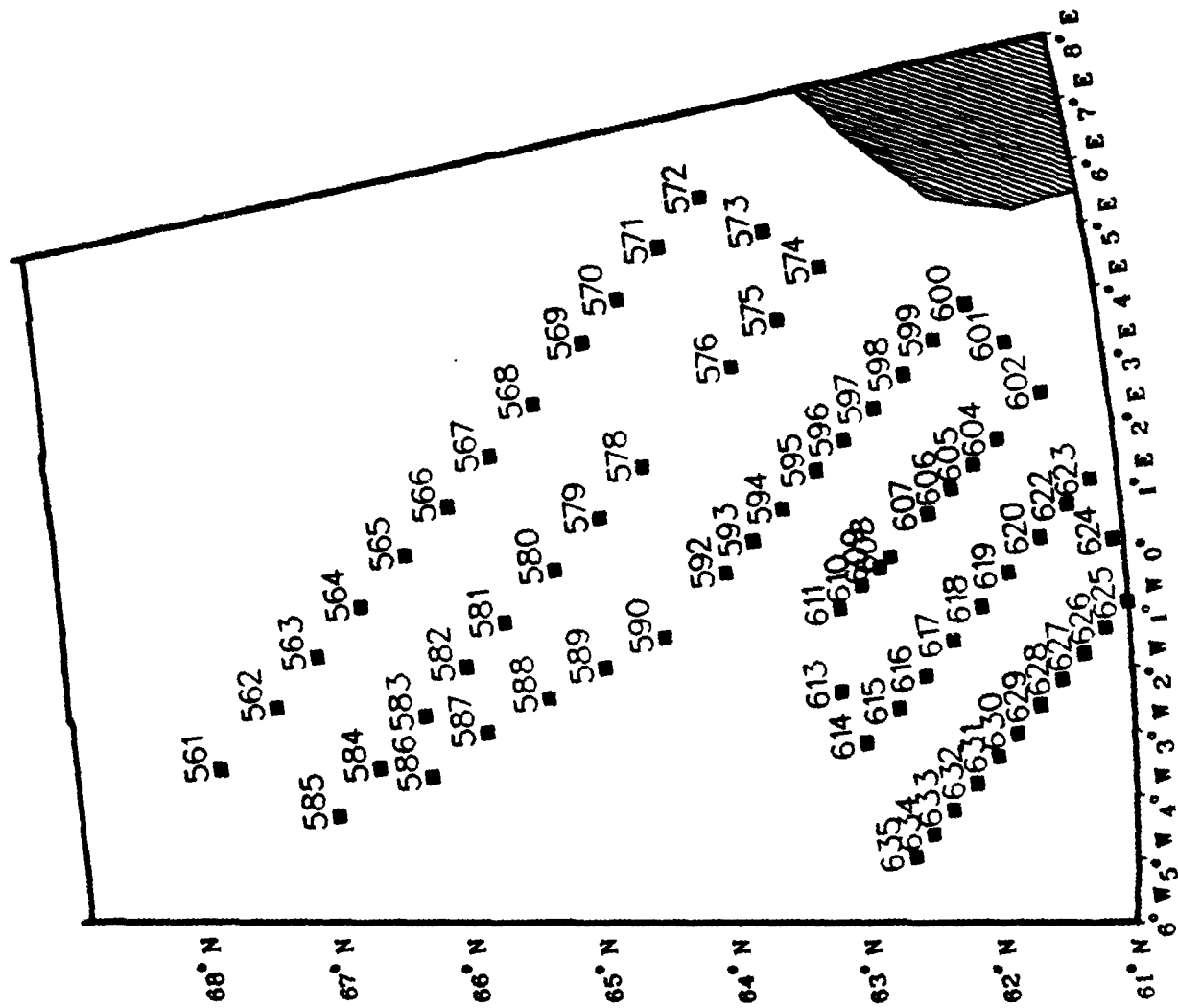




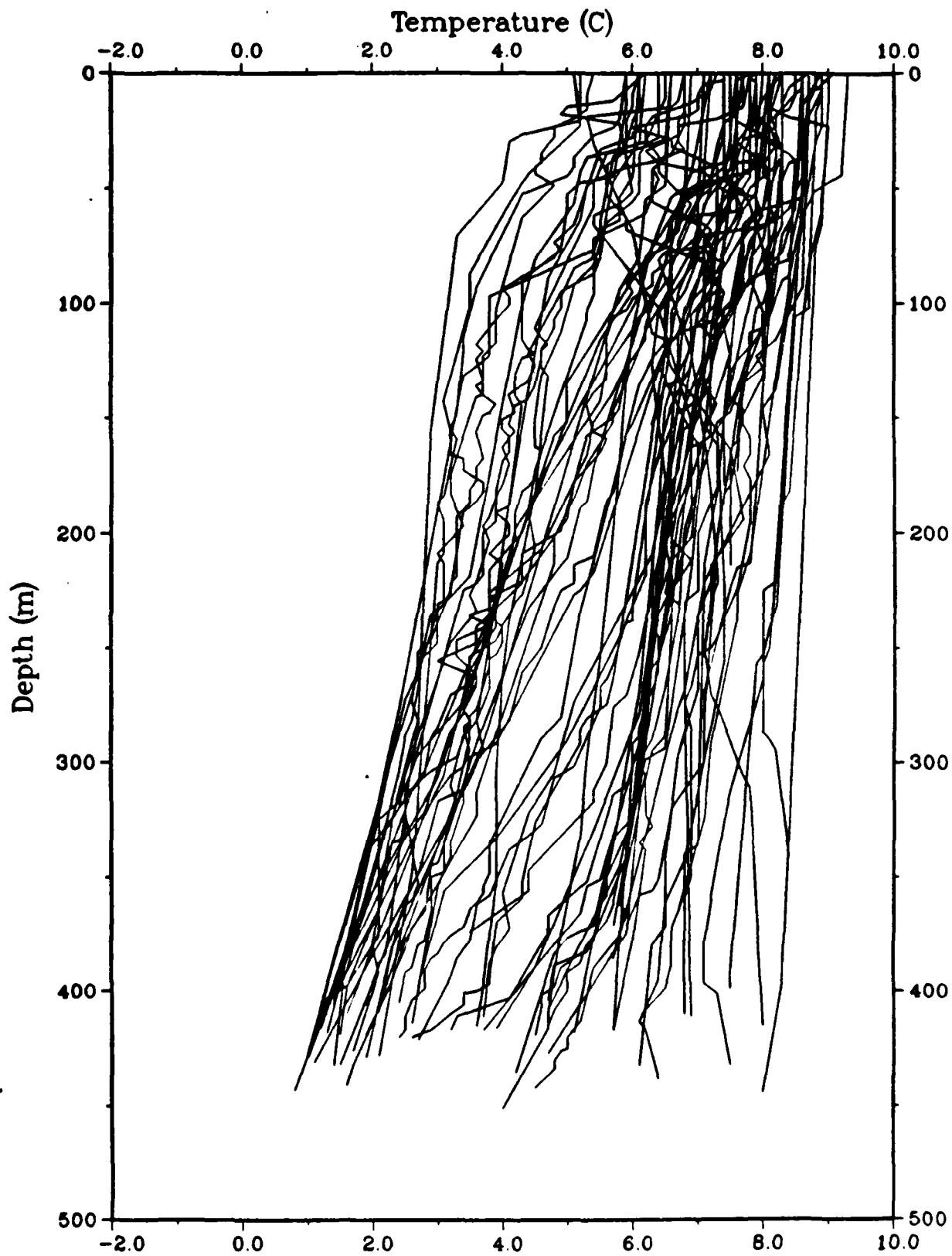
G MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



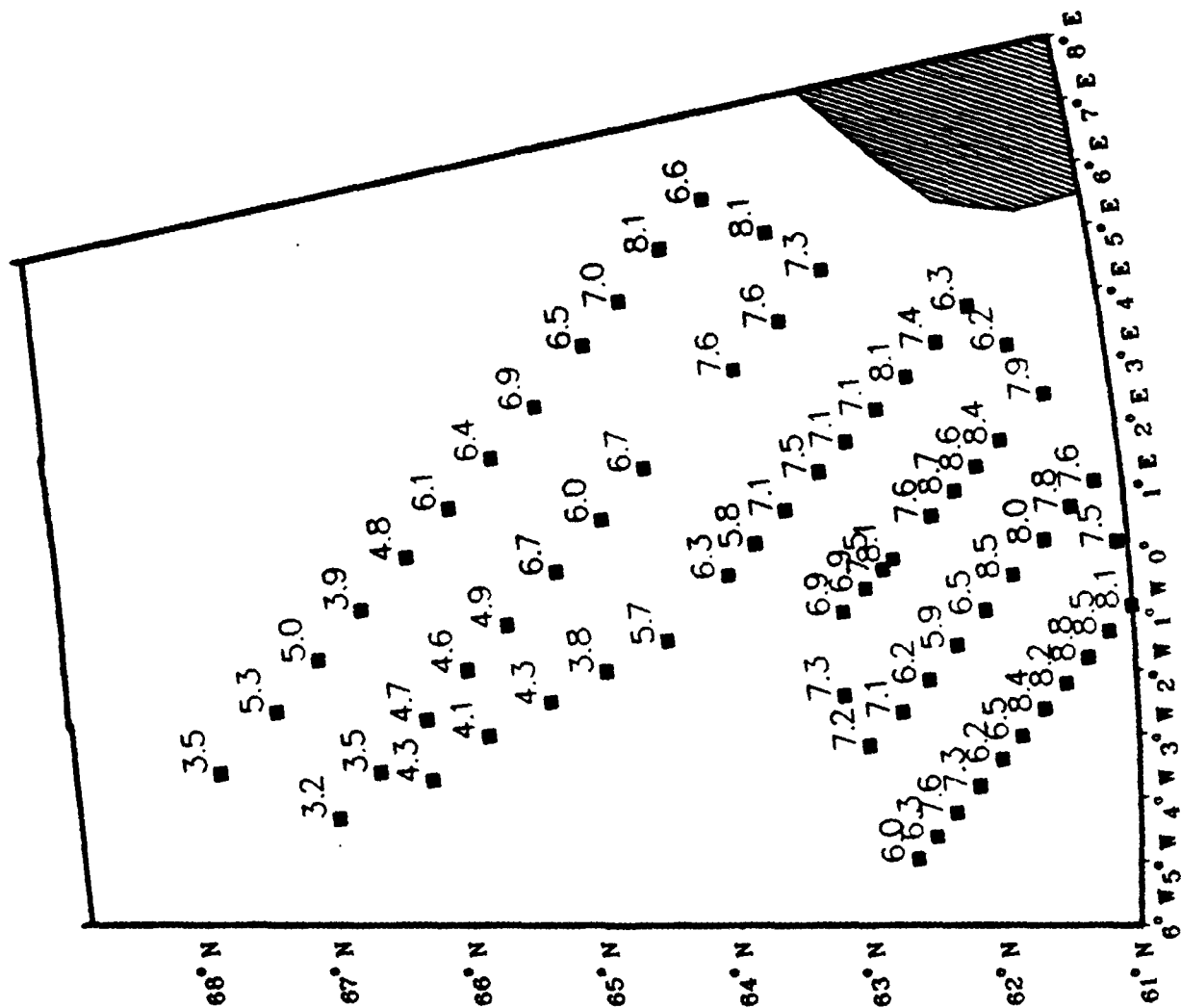
28 May 87 AXBT Stations



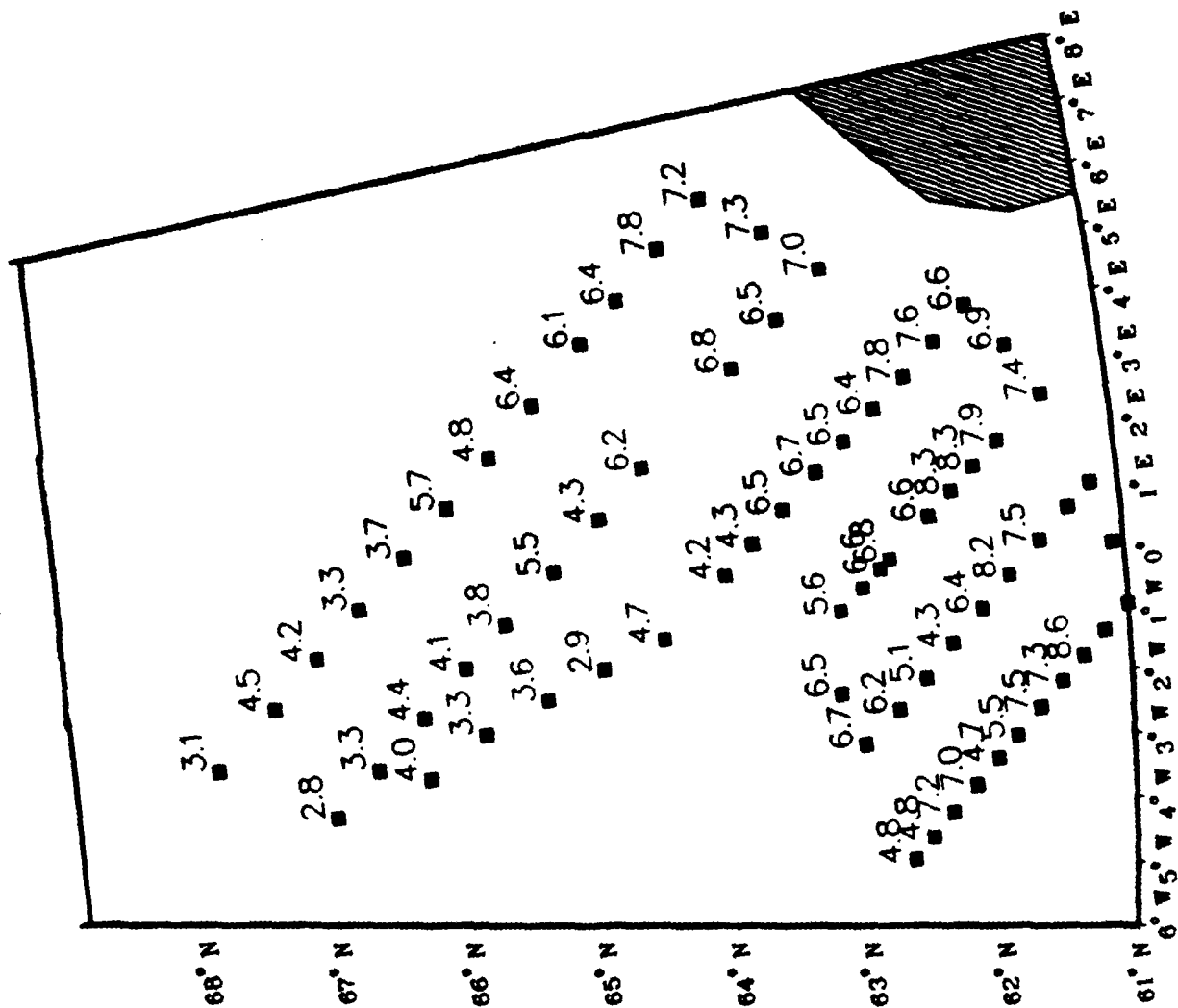
28 May 1987



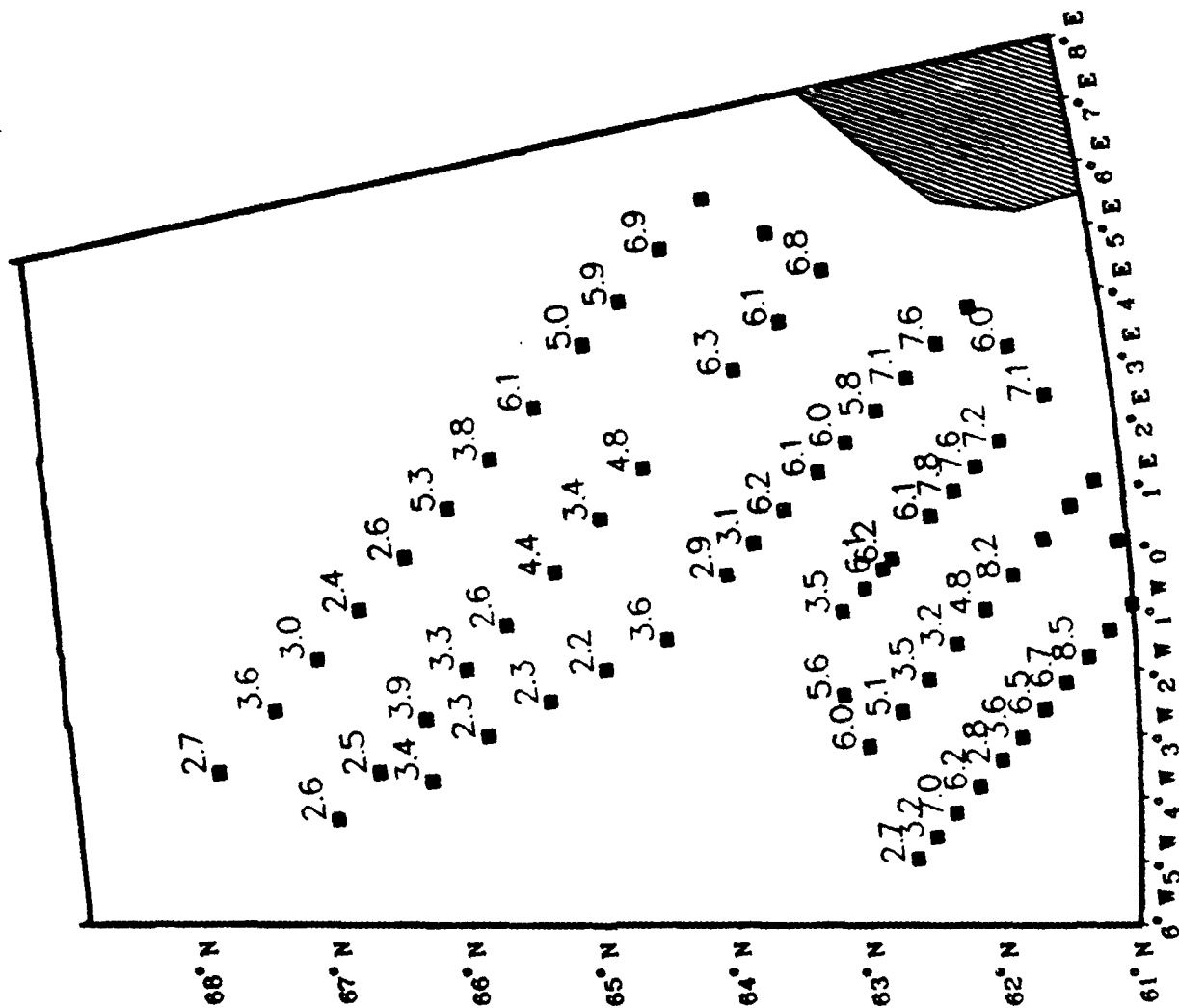
28 May 1987
100 meters



28 May 1987
200 meters

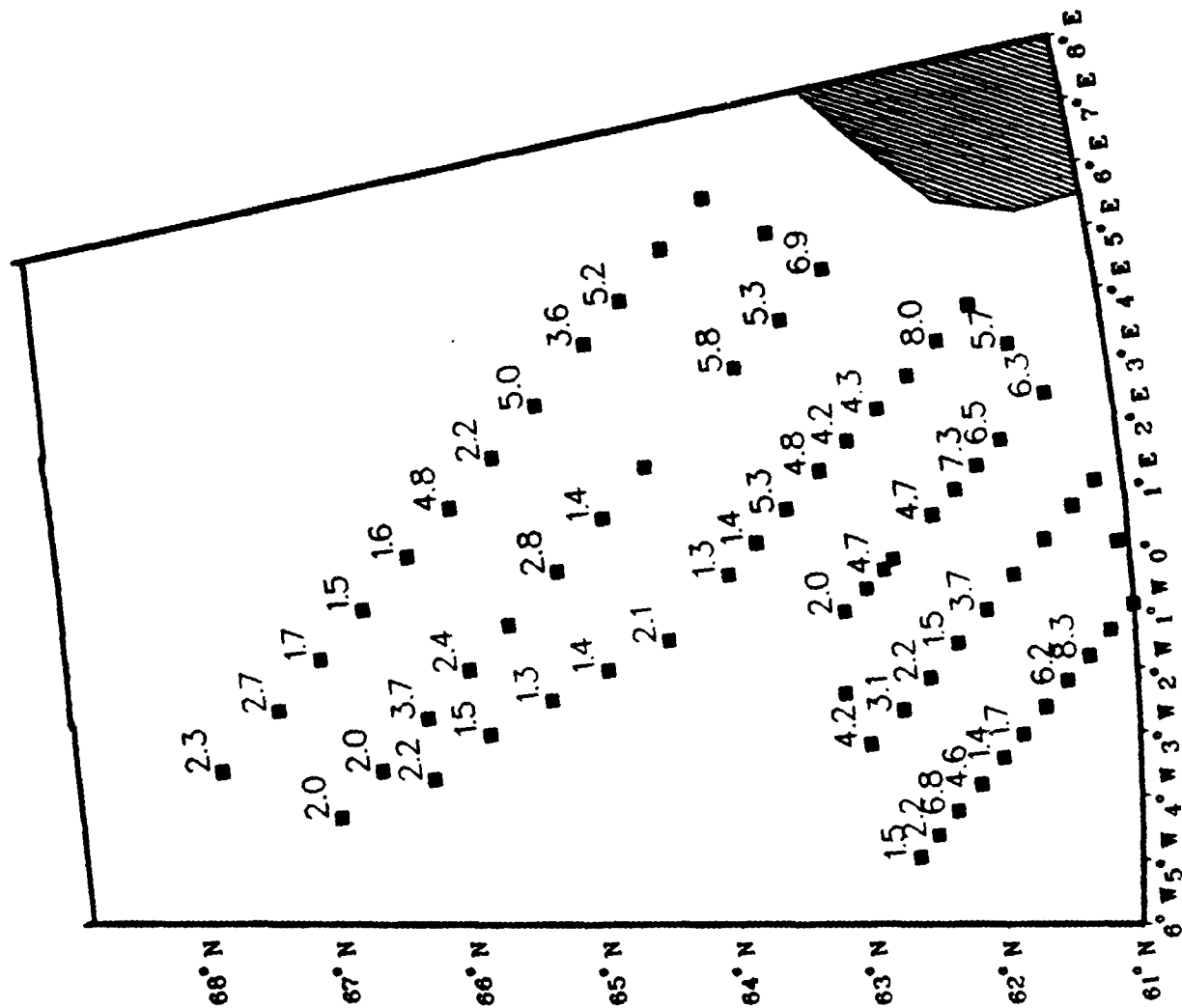


28 May 1987
300 meters

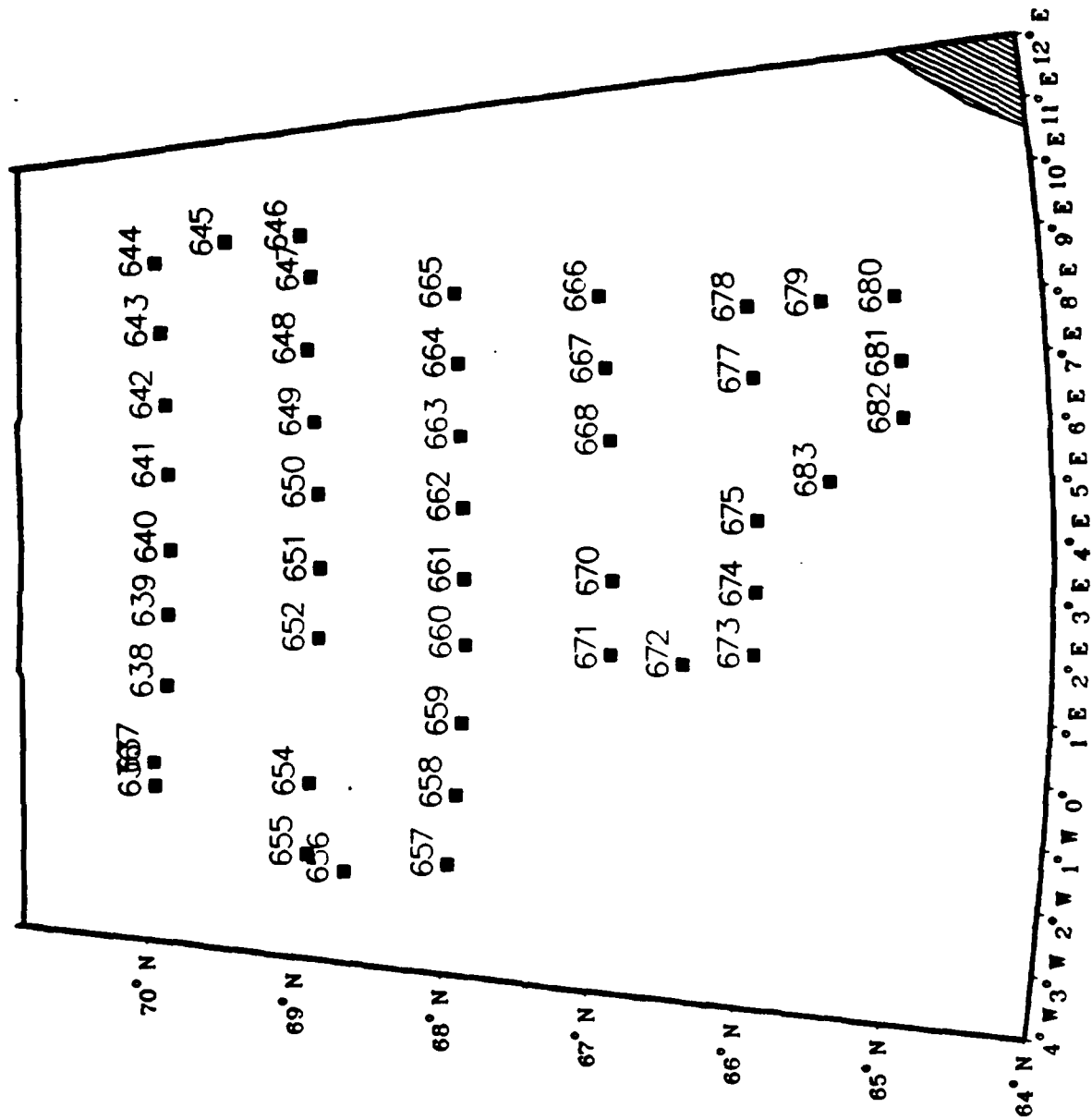


61°N 6°W 5°W 4°W 3°W 2°W 1°W 0° 1°E 2°E 3°E 4°E 5°E 6°E 7°E 8°E

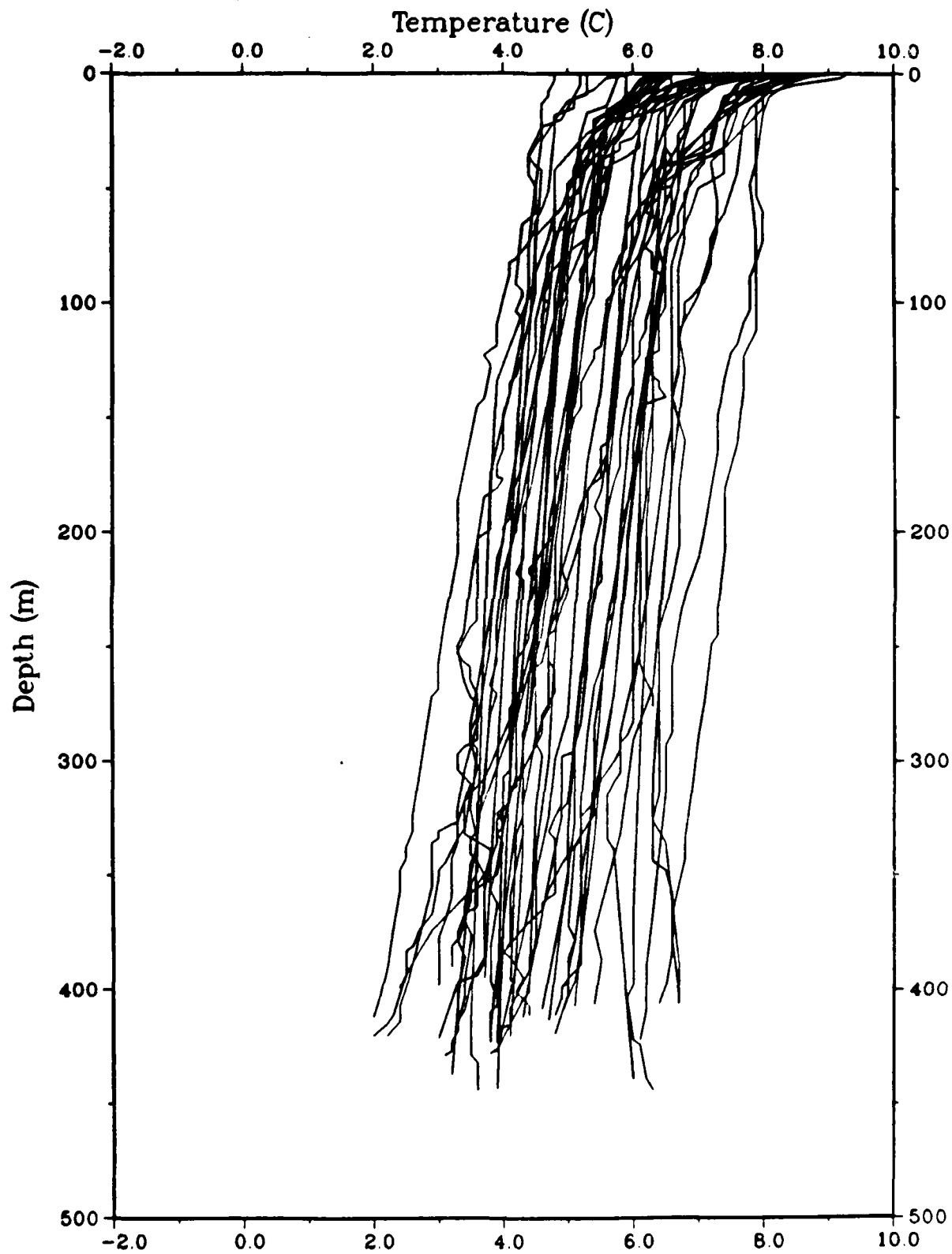
28 May 1987
400 meters



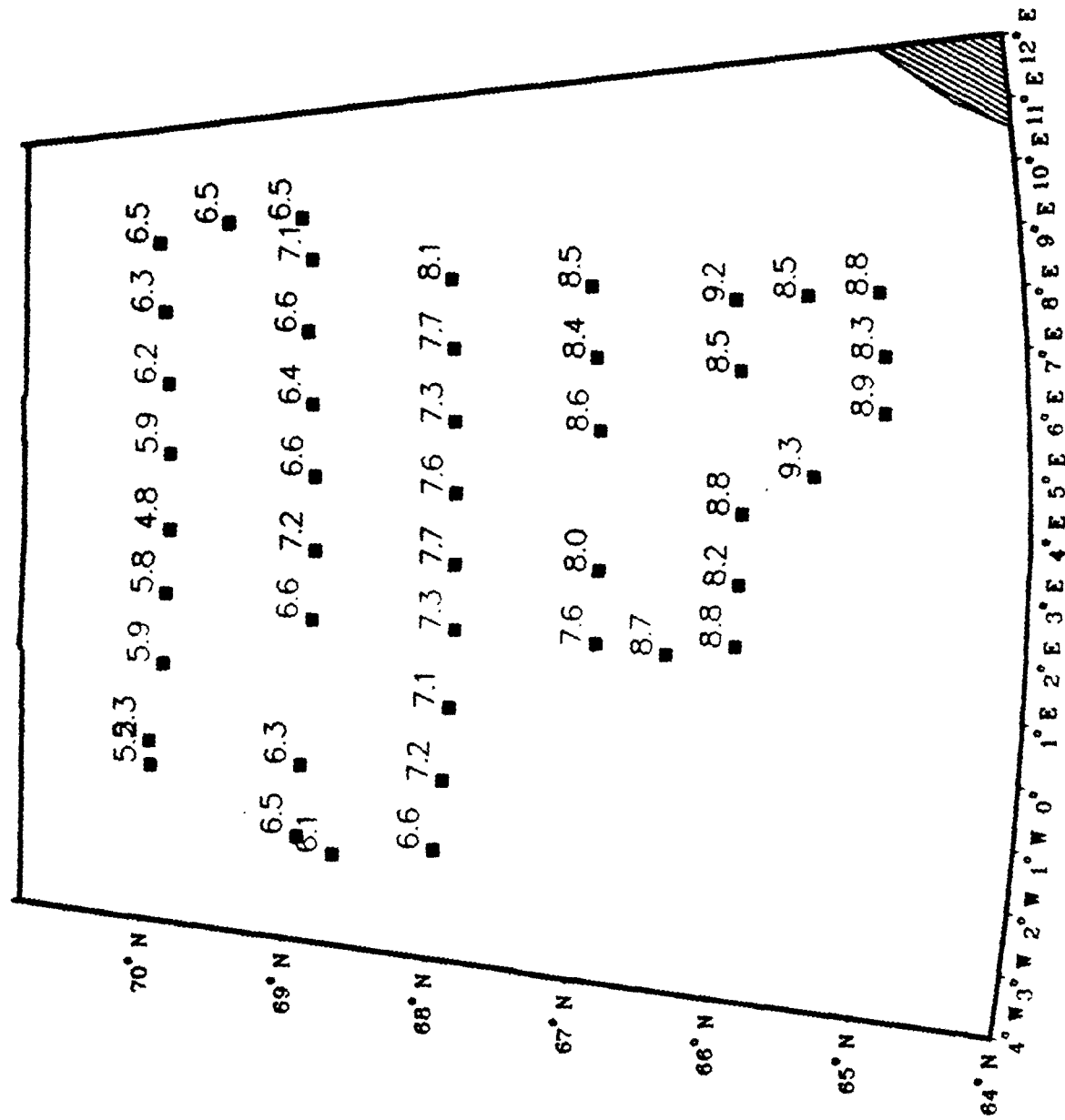
30 May 1987 AXBT Stations



30 May 1987



30 May 1987
0 meters

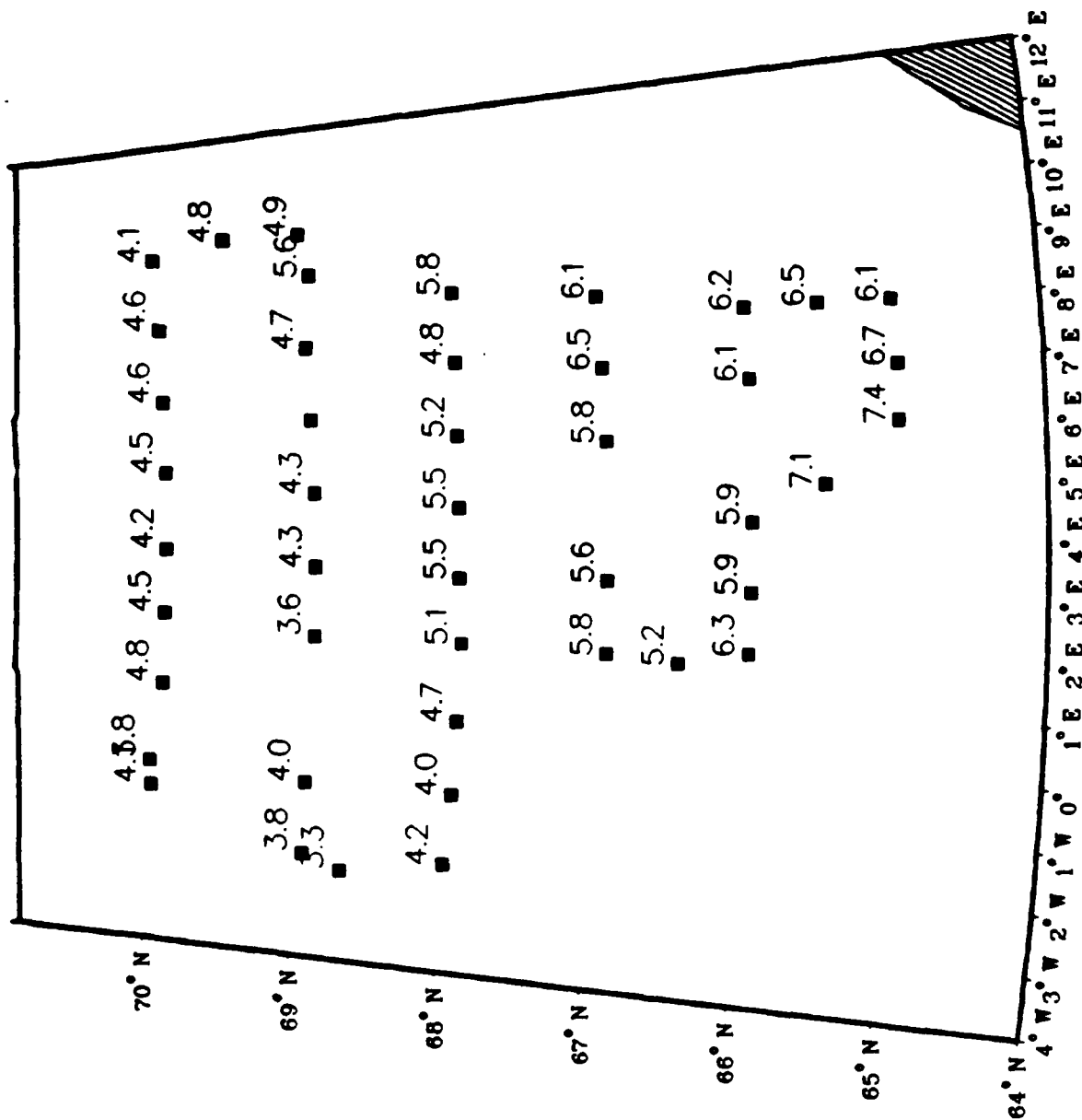


4 5 6 7 8 9 10 11 12

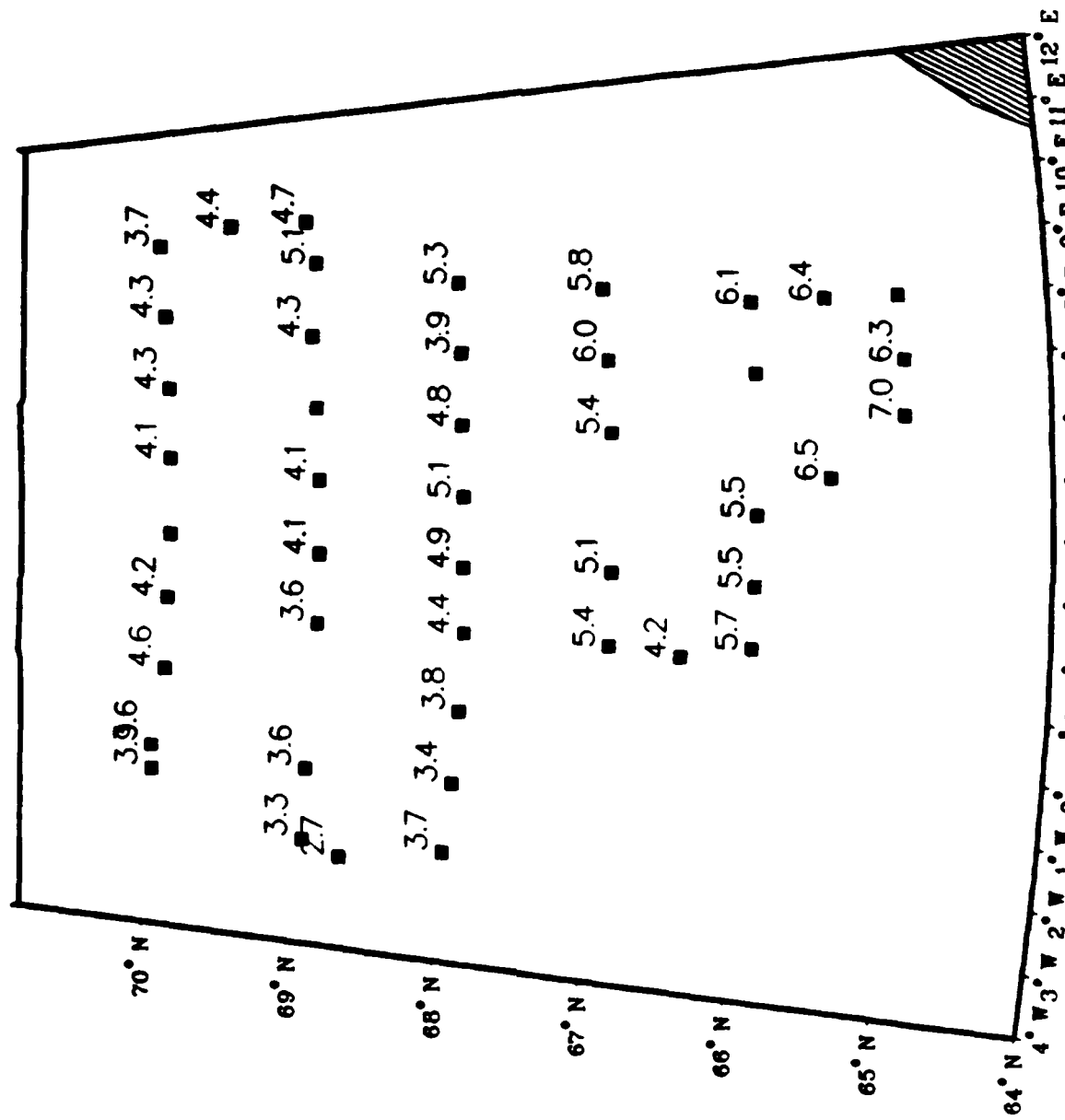
Map of the study area showing sampling stations and depth measurements. The map covers a region from 4°W to 12°E and 64°N to 70°N. Sampling stations are marked with black squares and labeled with depth values in meters. The depth values range from 4.0 to 7.9 meters. The map includes latitude and longitude coordinates along the edges and a shaded area in the top right corner.

| Latitude (°N) | Longitude (°W/°E) | Depth (m) |
|---------------|-------------------|-----------|
| 70° | 10°E | 4.3 |
| 70° | 10°E | 4.4 |
| 70° | 10°E | 5.3 |
| 70° | 10°E | 4.9 |
| 70° | 10°E | 4.4 |
| 70° | 10°E | 4.8 |
| 70° | 10°E | 4.9 |
| 70° | 10°E | 4.8 |
| 70° | 10°E | 5.3 |
| 69° | 10°E | 4.4 |
| 69° | 10°E | 4.6 |
| 69° | 10°E | 4.5 |
| 69° | 10°E | 5.0 |
| 69° | 10°E | 4.6 |
| 69° | 10°E | 5.4 |
| 69° | 10°E | 6.1 |
| 69° | 10°E | 5.2 |
| 68° | 10°E | 4.9 |
| 68° | 10°E | 4.7 |
| 68° | 10°E | 5.6 |
| 68° | 10°E | 5.8 |
| 68° | 10°E | 6.0 |
| 68° | 10°E | 5.9 |
| 68° | 10°E | 5.7 |
| 68° | 10°E | 5.2 |
| 68° | 10°E | 6.4 |
| 67° | 10°E | 6.3 |
| 67° | 10°E | 5.8 |
| 67° | 10°E | 6.4 |
| 67° | 10°E | 6.9 |
| 67° | 10°E | 6.5 |
| 66° | 10°E | 5.9 |
| 66° | 10°E | 6.8 |
| 66° | 10°E | 6.4 |
| 66° | 10°E | 6.4 |
| 66° | 10°E | 6.3 |
| 66° | 10°E | 6.3 |
| 65° | 10°E | 7.8 |
| 65° | 10°E | 7.9 |
| 65° | 10°E | 6.6 |
| 65° | 10°E | 6.3 |

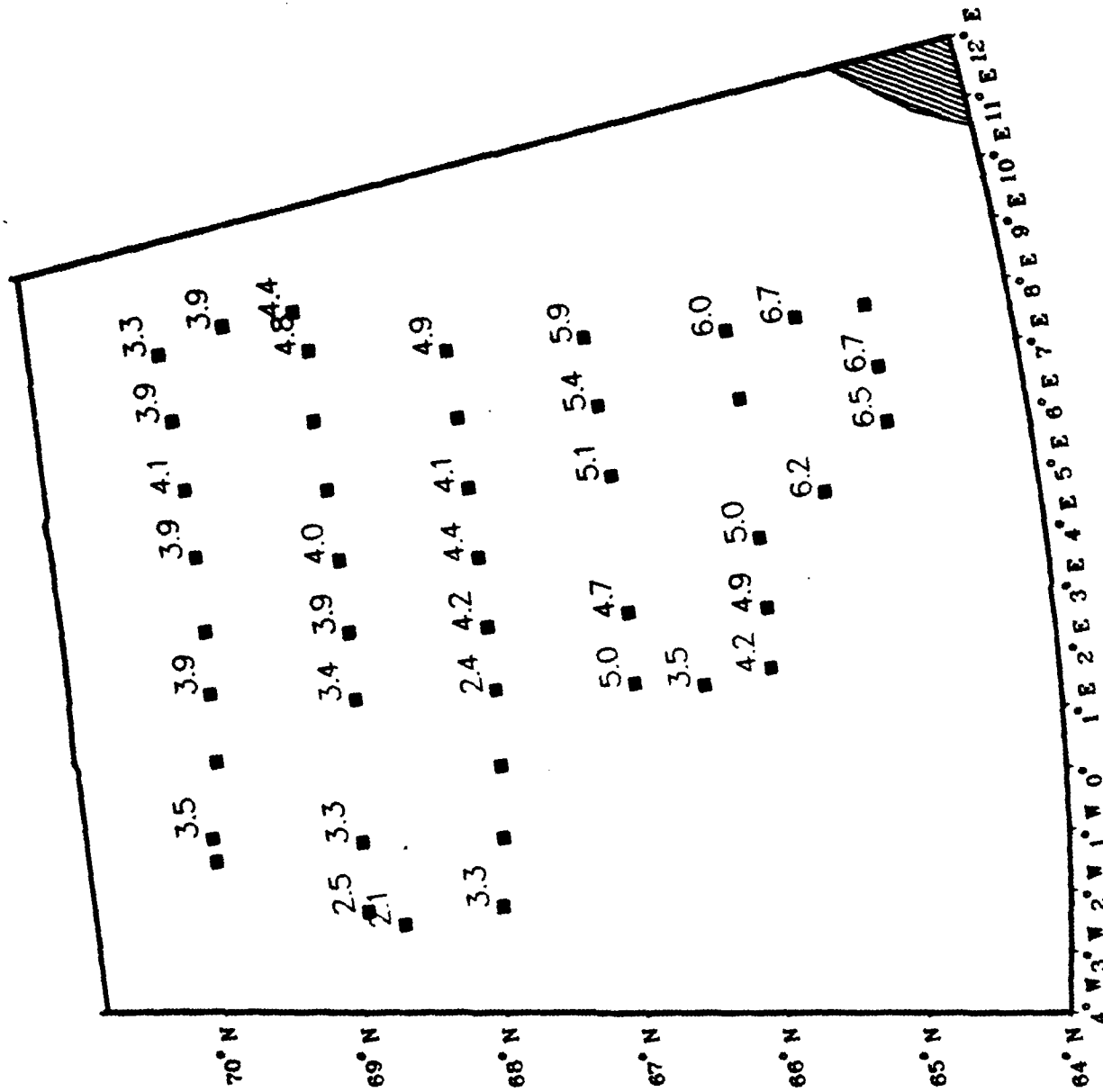
30 May 1987
200 meters



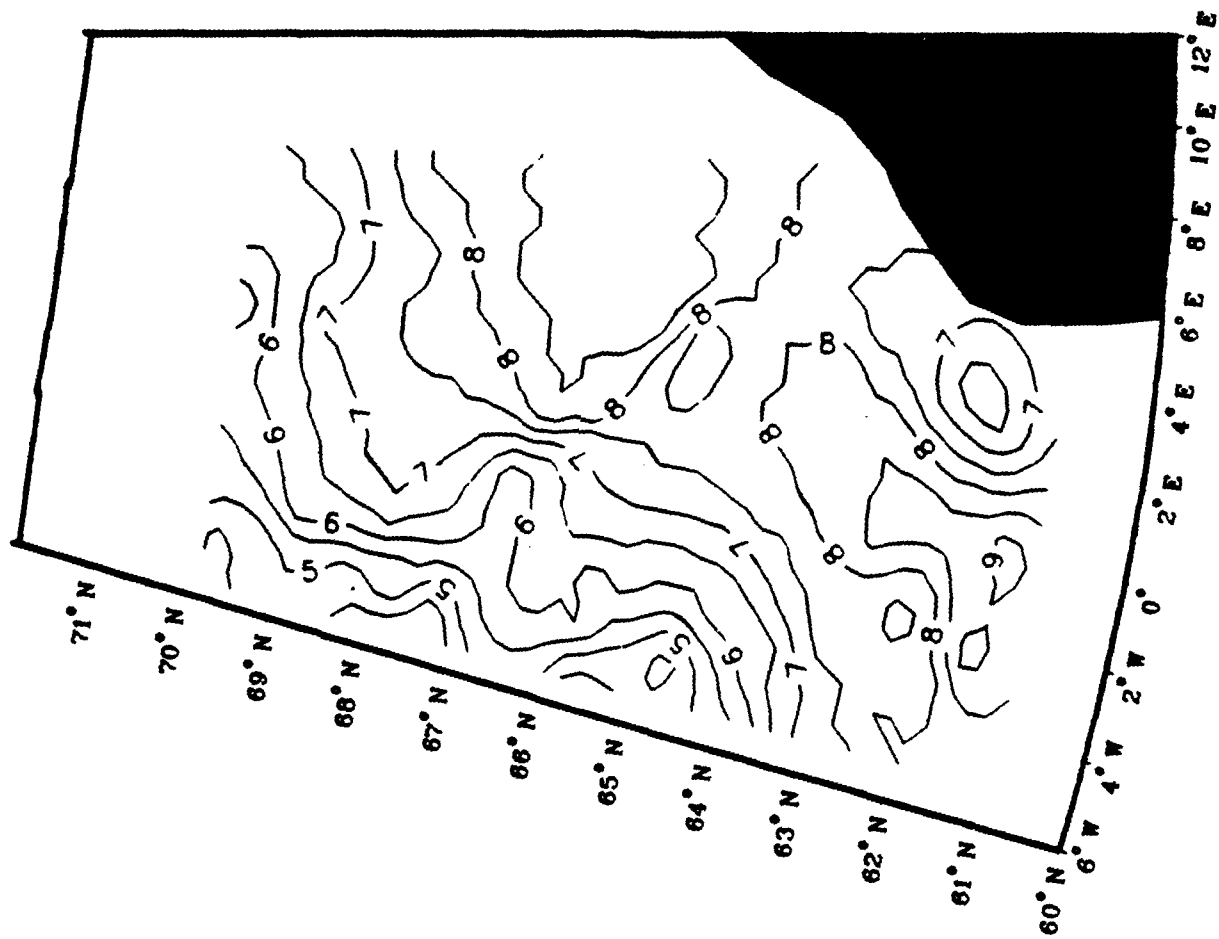
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300 meters



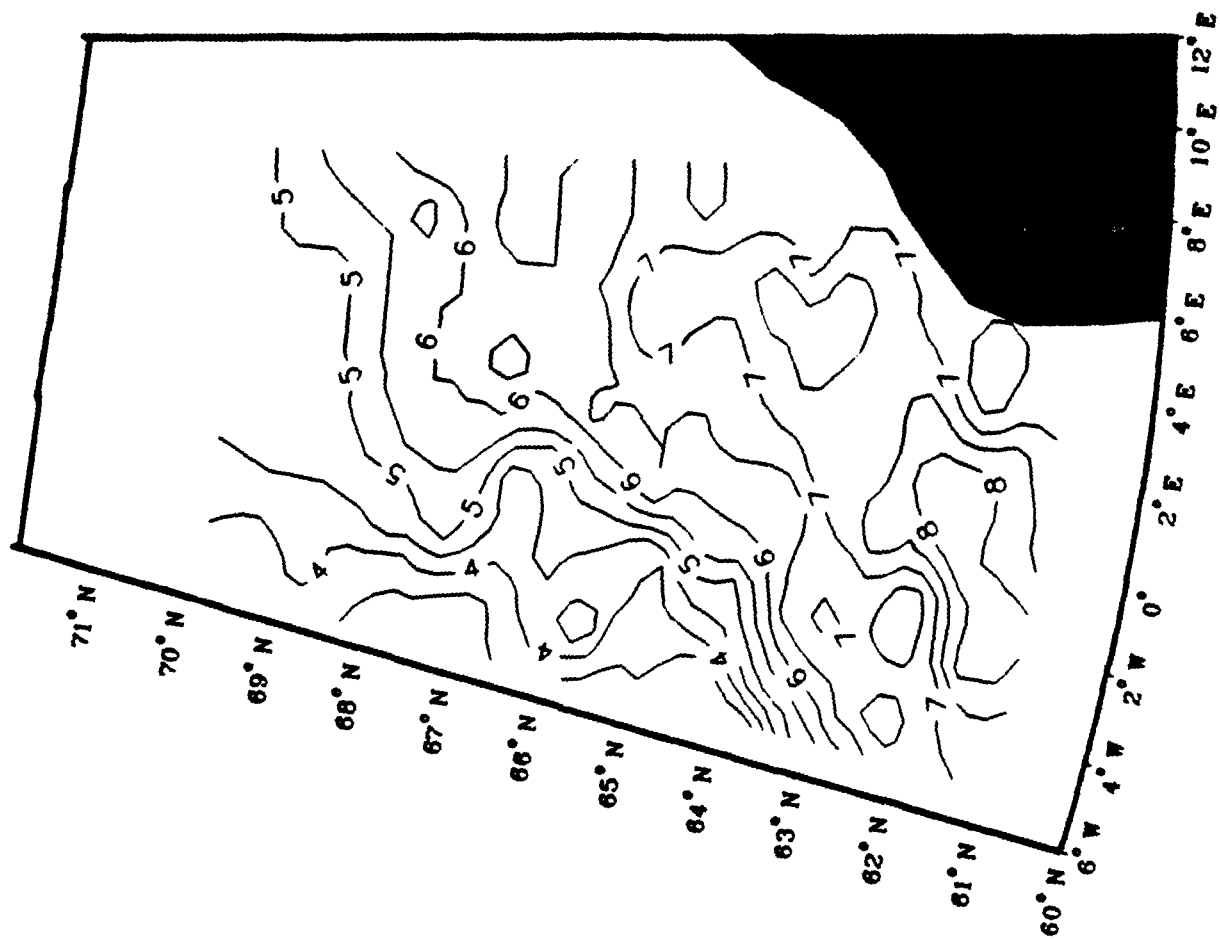
30 May 1987
400 meters



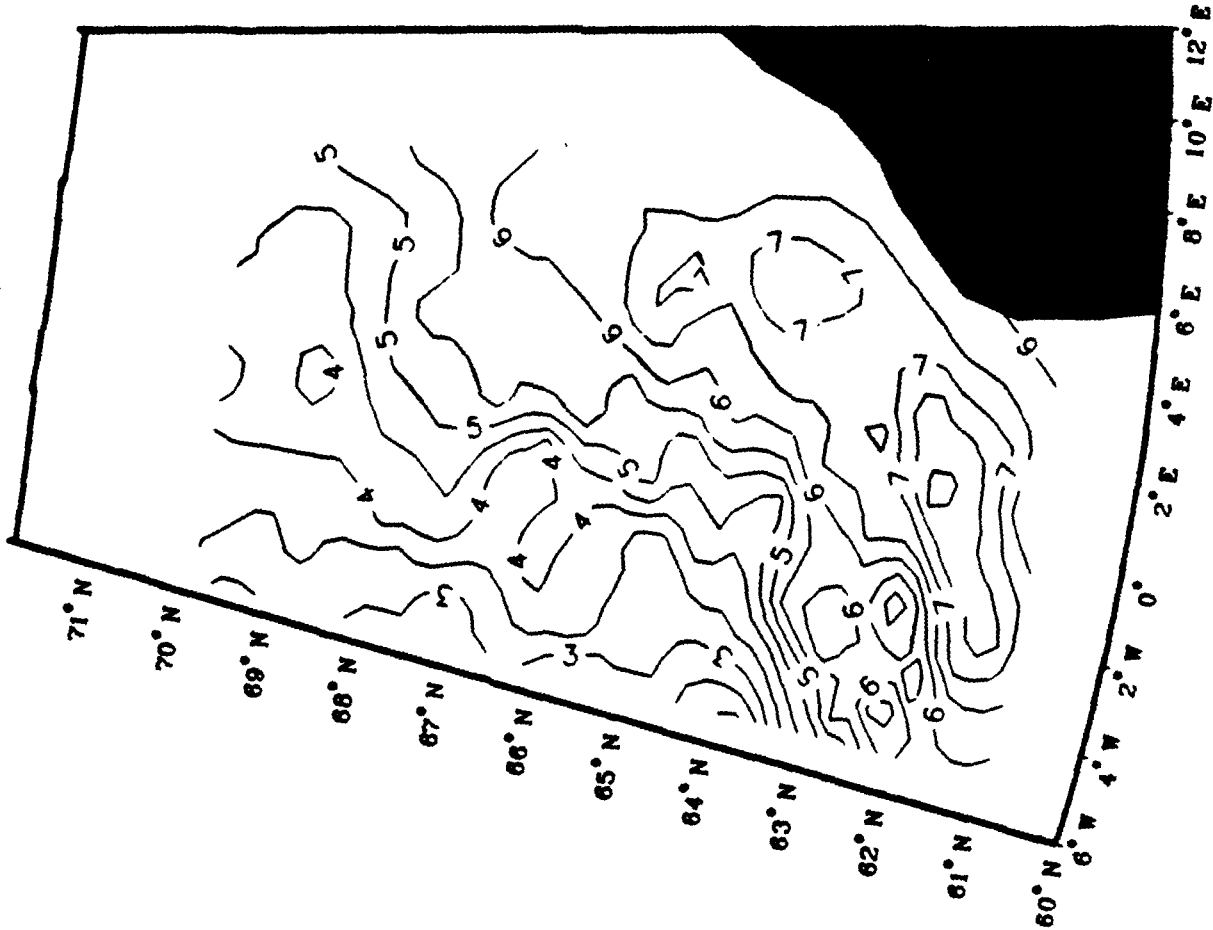
Temperature
28-30 May 1987
0 meters



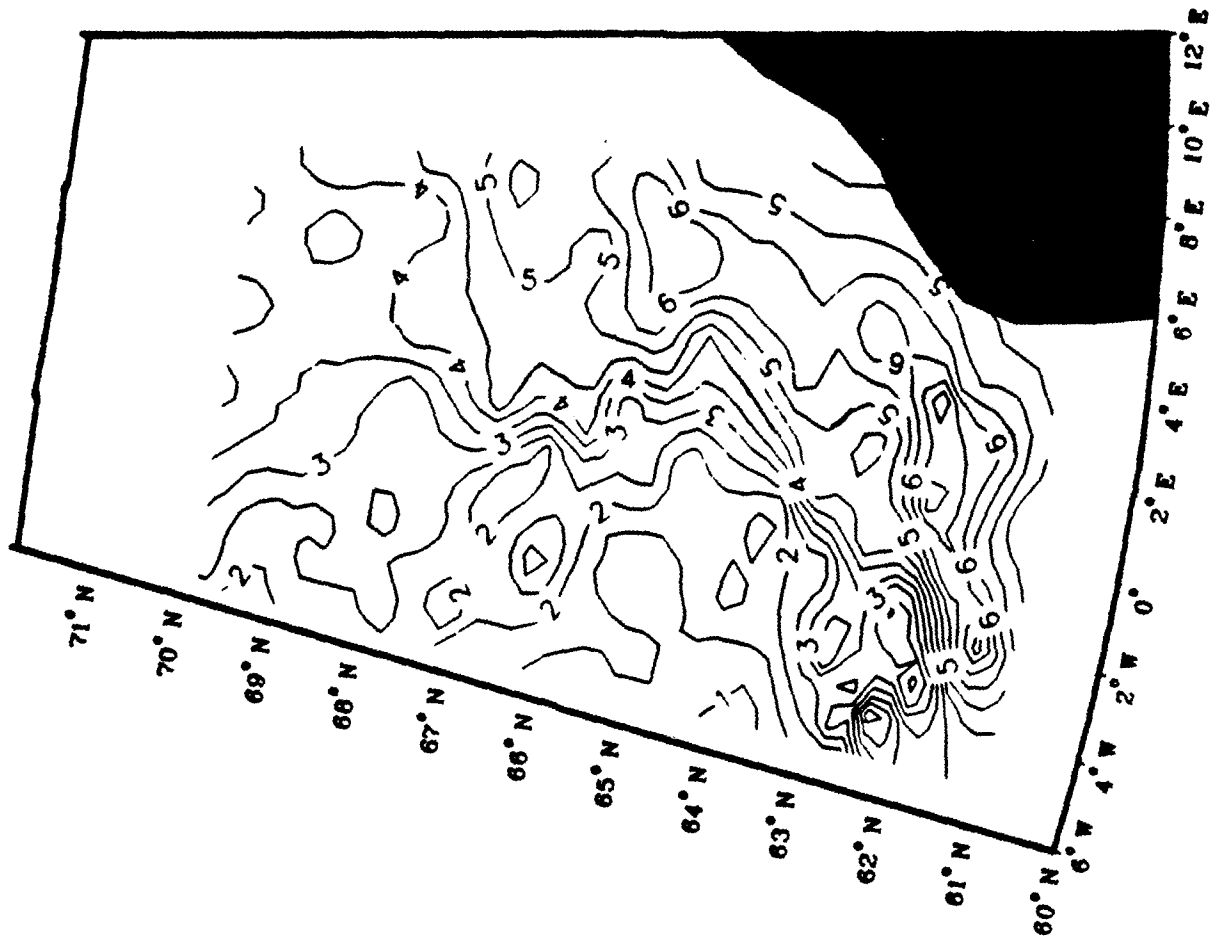
Temperature
28-30 May 1987
100 meters



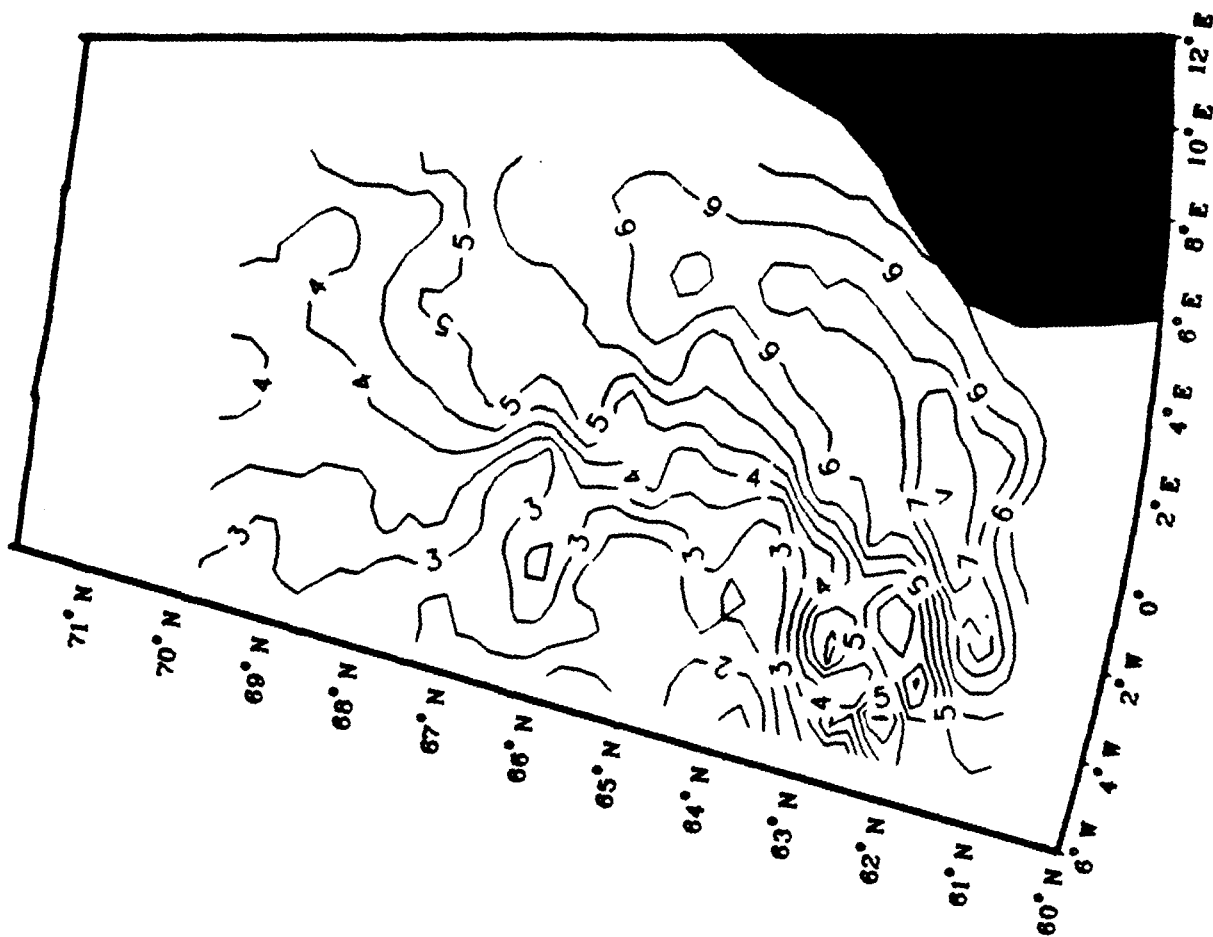
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28-30 May 1987
200 meters

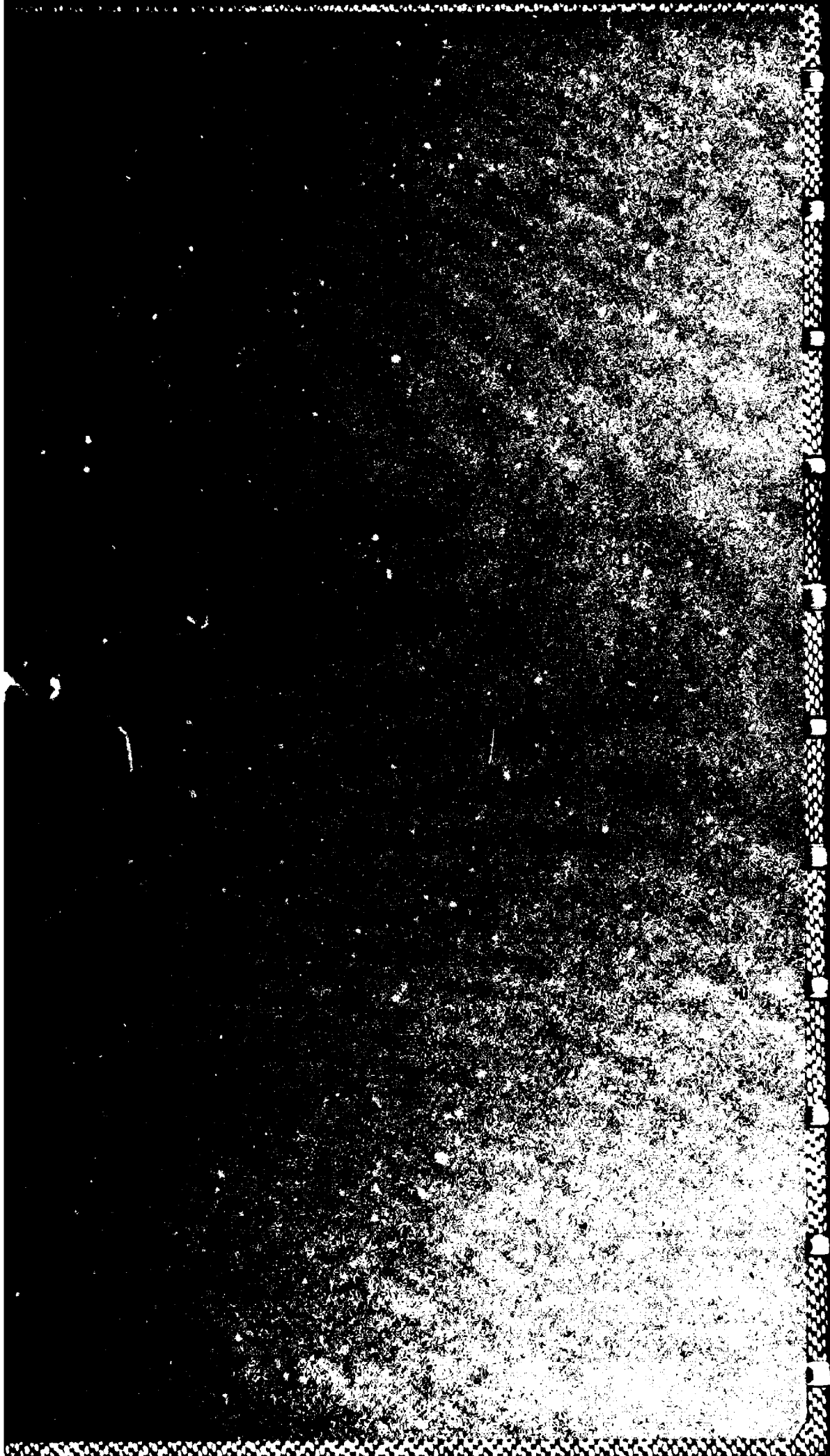


Temperature
28-30 May 1987
400 meters



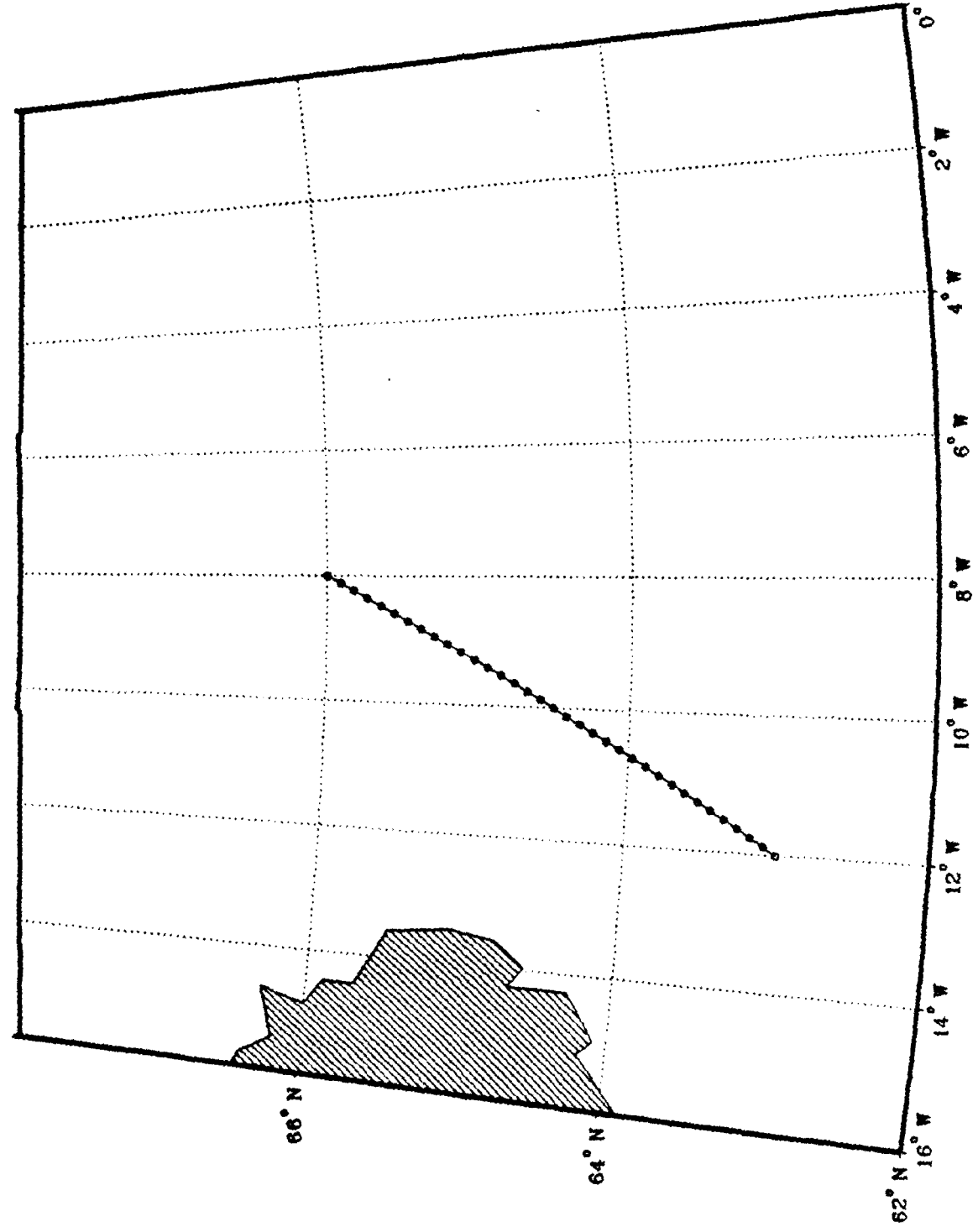
Temperature
28-30 May 1987
300 meters



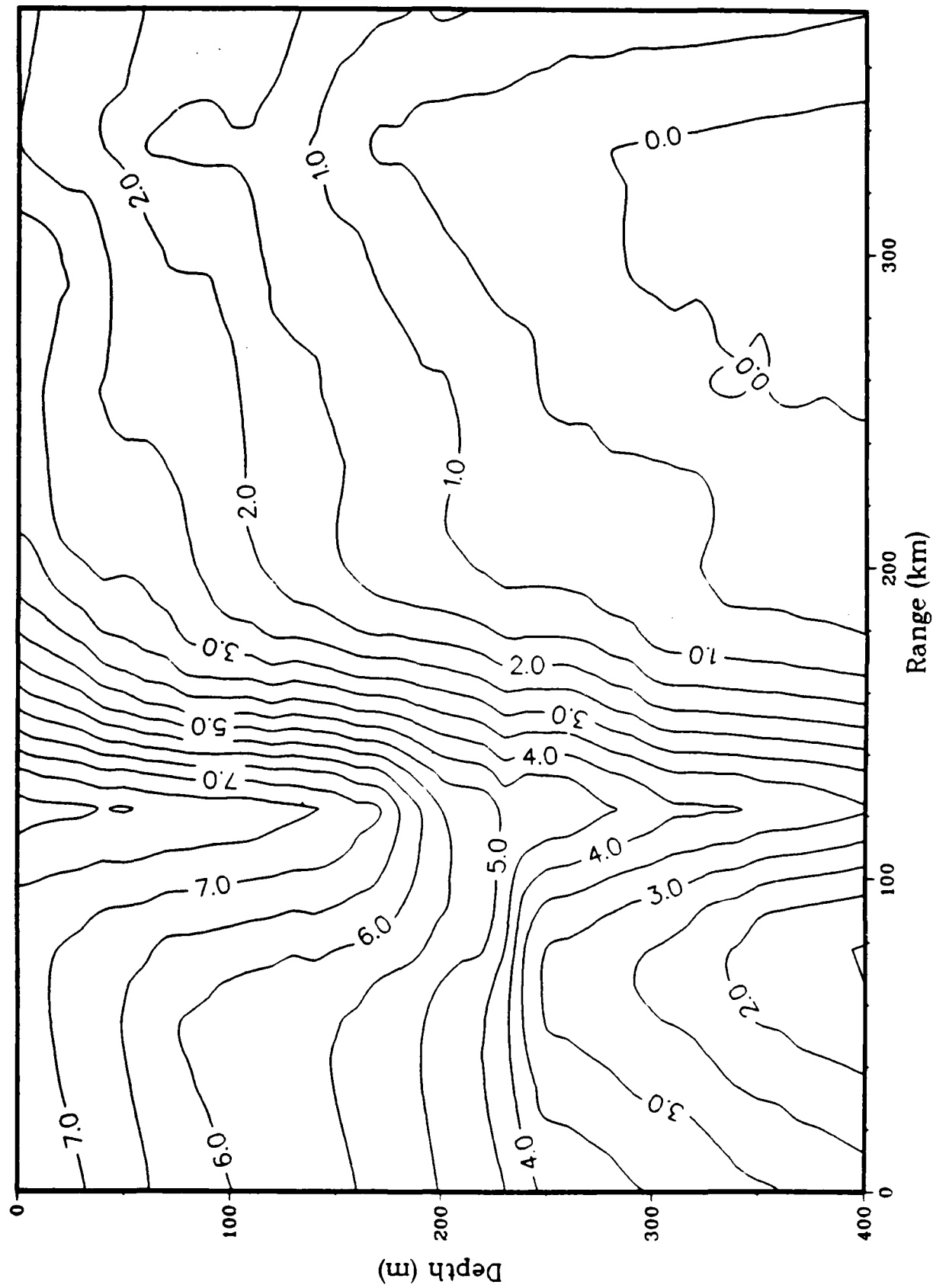


**Transacts through
Front**

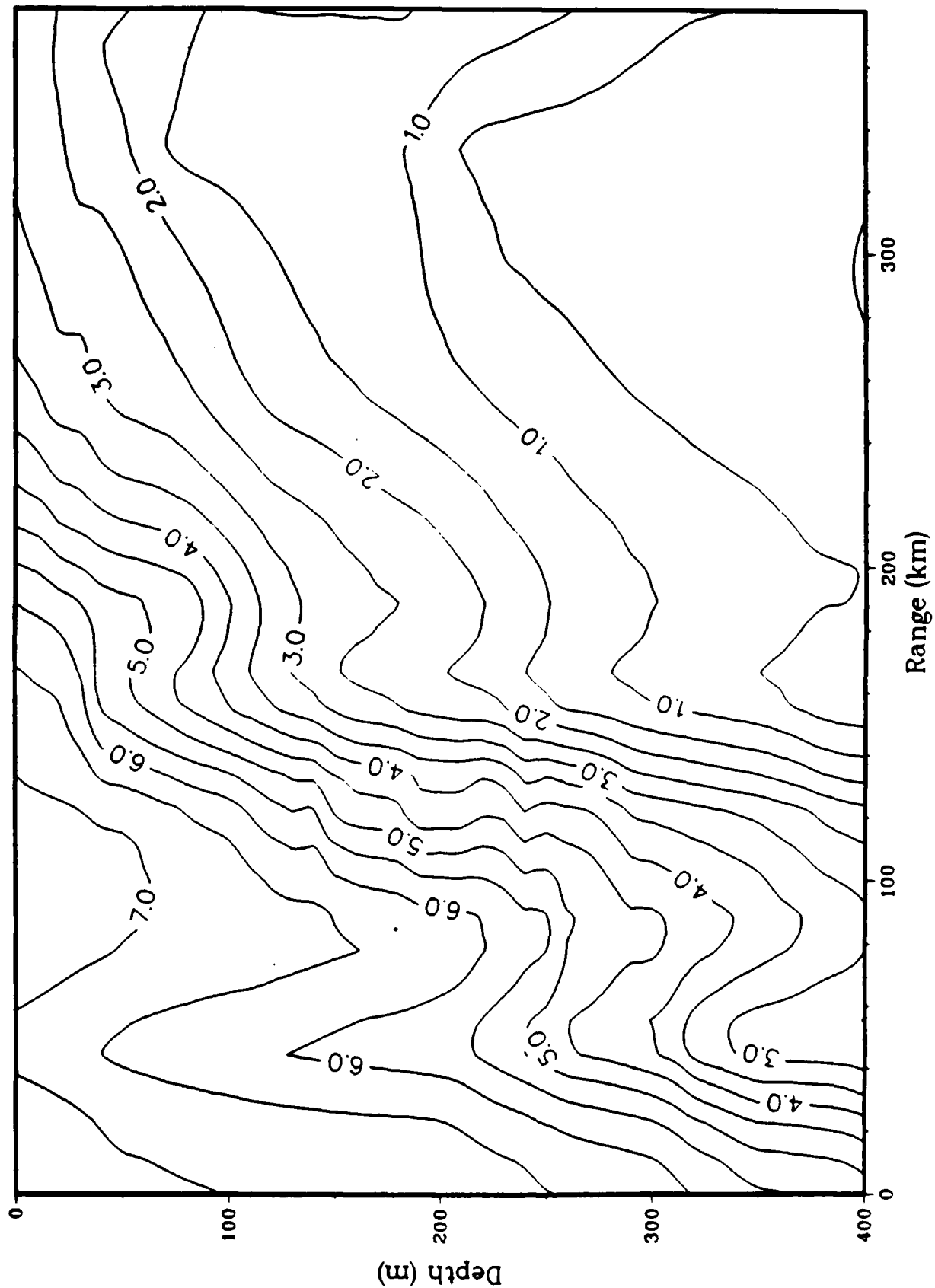
15-26 May 1987
(-12.0, 63.0) to (-8.0, 66.0)



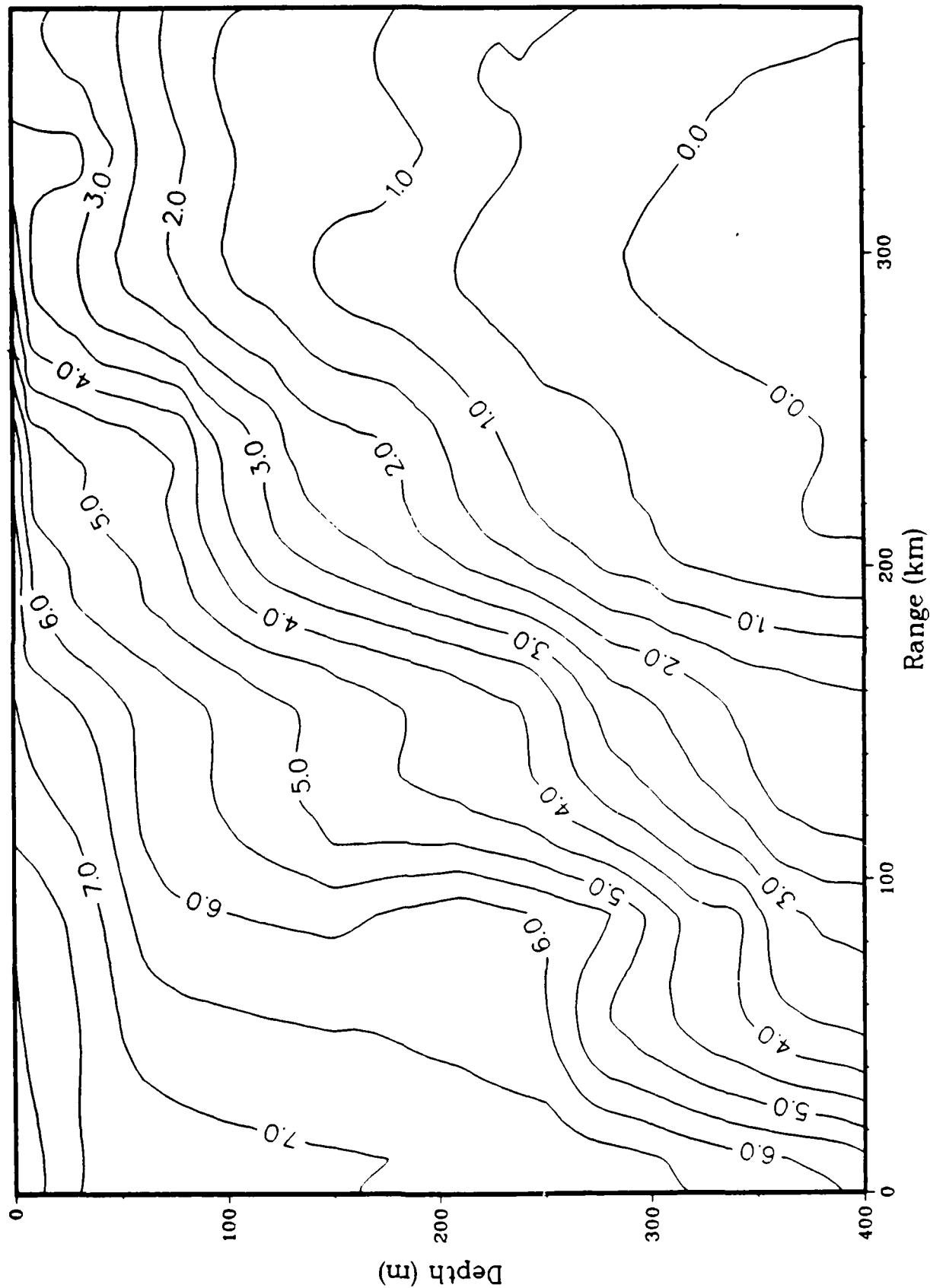
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15 May 1987
(-12.0, 63.0) to (-8.0, 66.0)



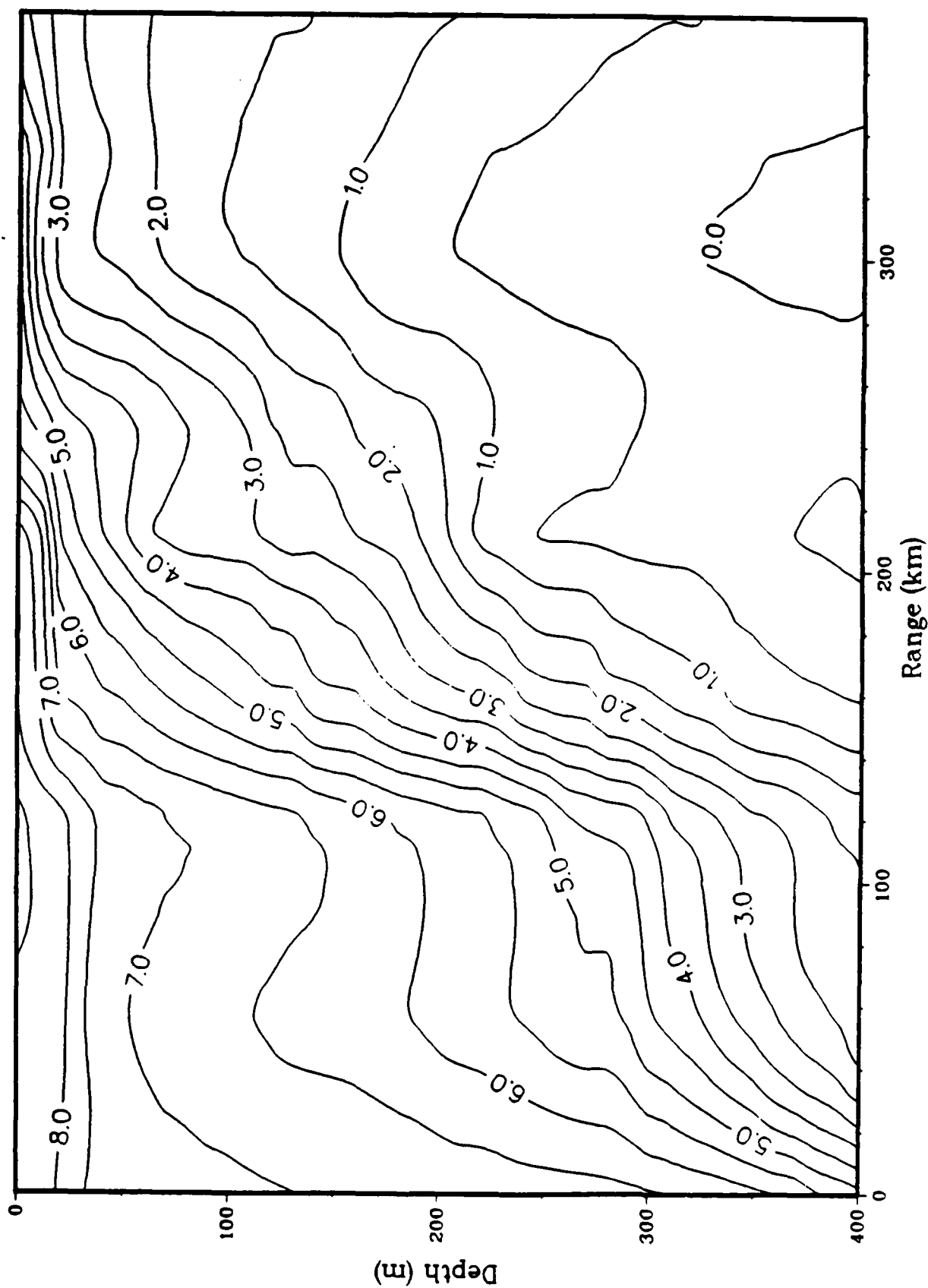
Temperature
18 May 1987
(-12.0, 63.0) to (-8.0, 66.0)



Temperature
22 May 1987
(-12.0, 63.0) to (-8.0, 66.0)

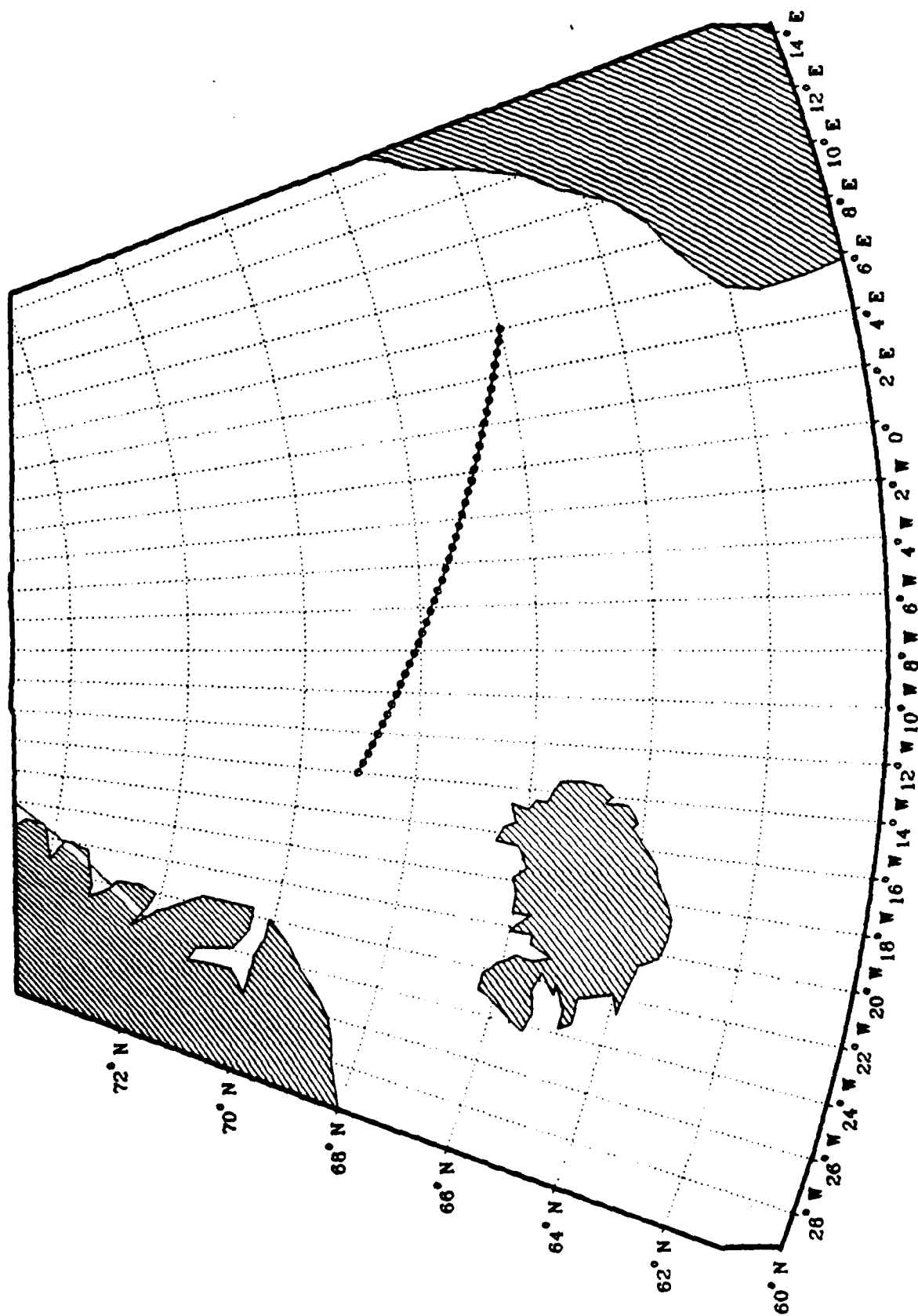


Temperature
26 May 1987
(-12.0, 63.0) to (-8.0, 66.0)

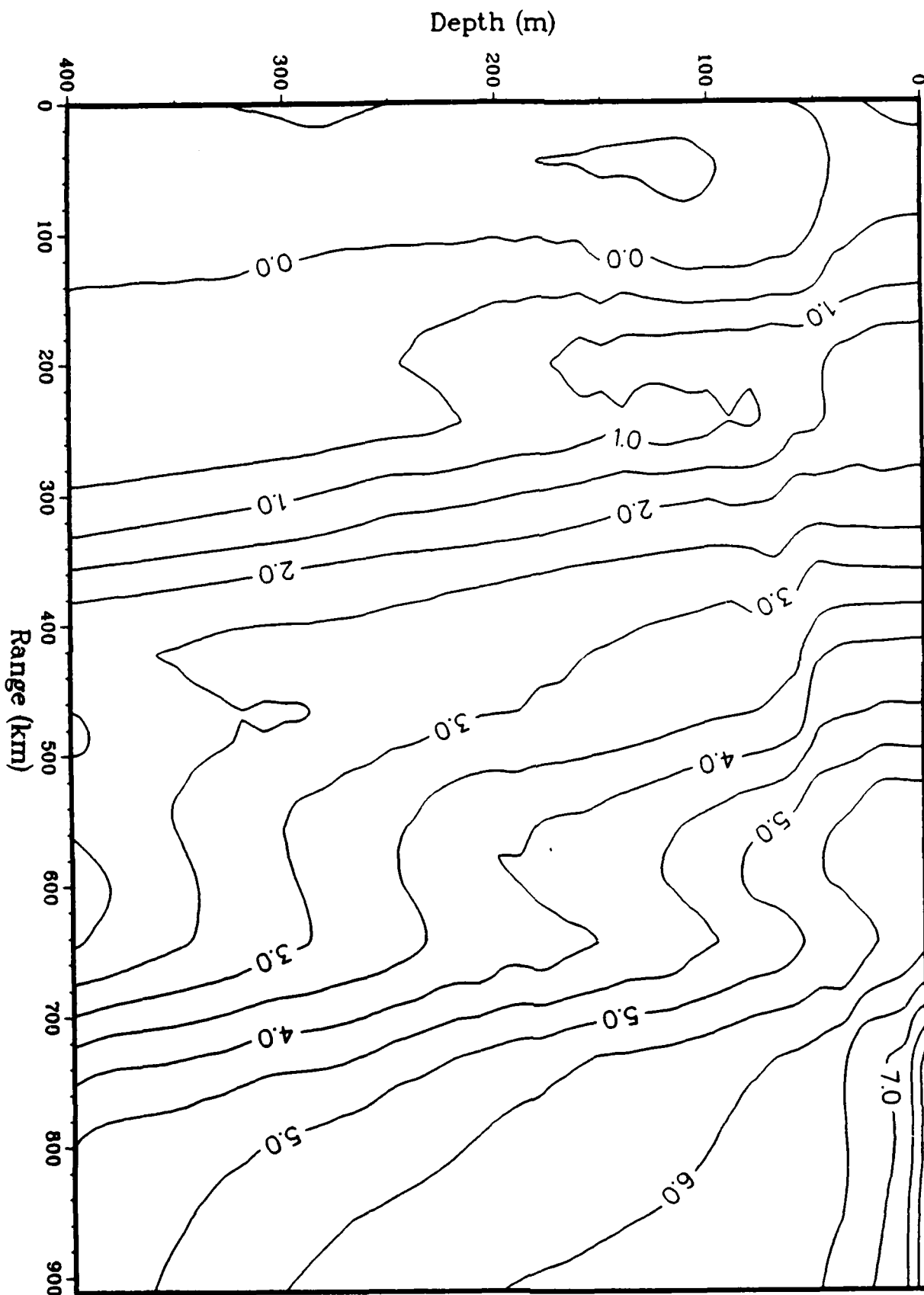


**Transect through
Jan Mayen and
Norwegian Current Fronts**

20-30 May 1987
(-14.0, 69.0) to (6.0, 66.0)

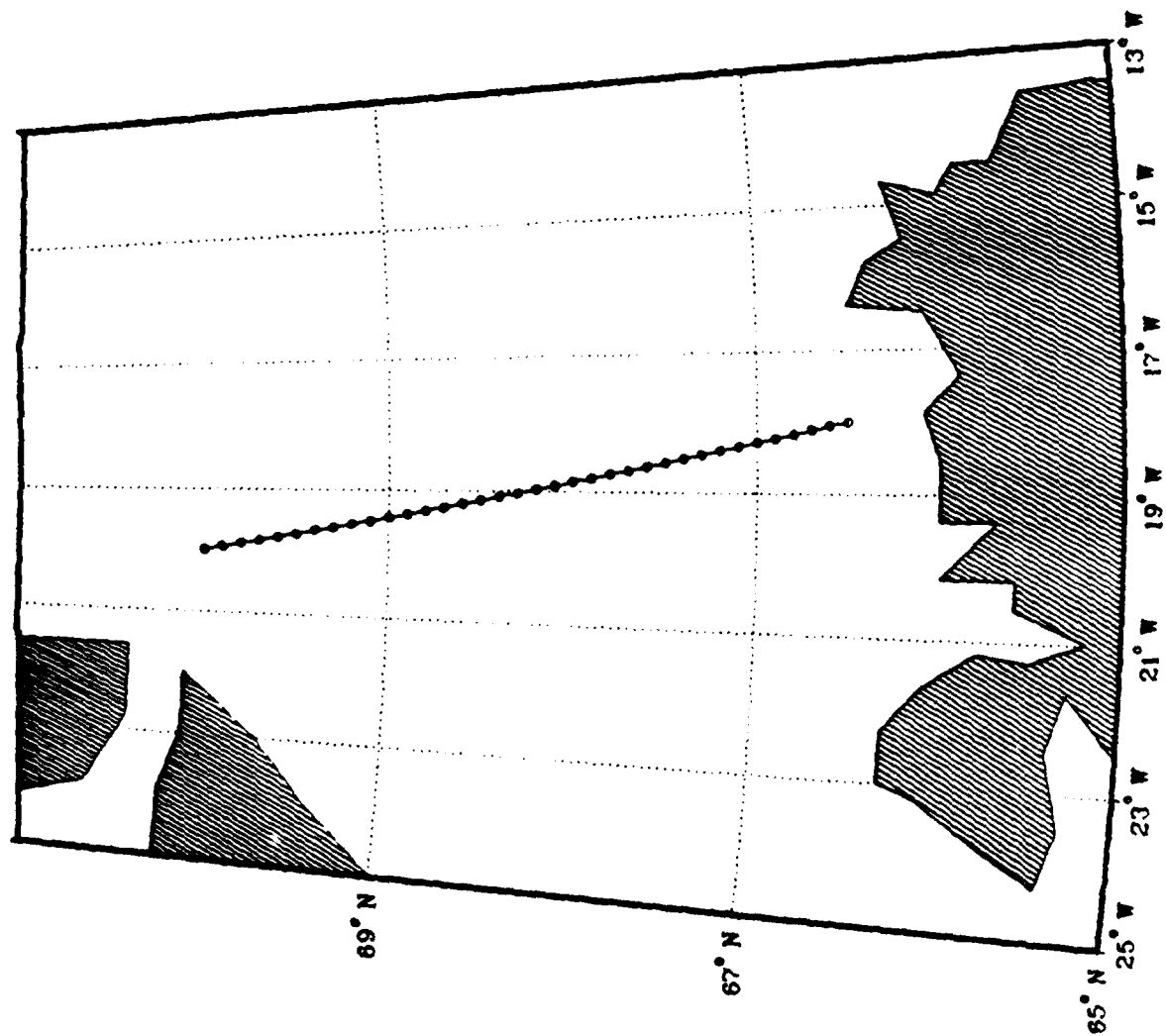


Temperature
20–30 May 1987
0, 69.0) to (6.0,

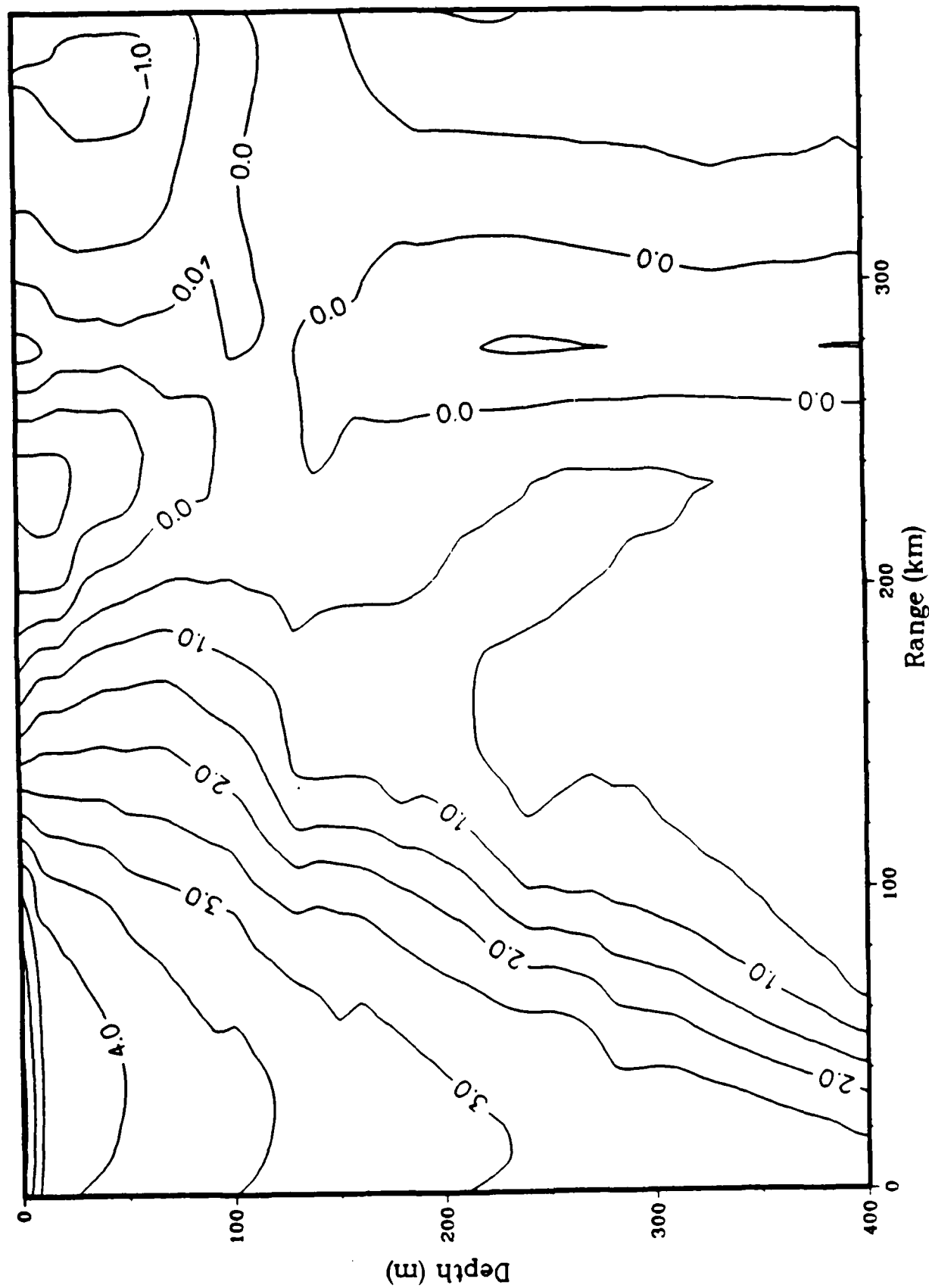


**Transect through
Primary Current Front**

24 May 1987
(-18.0, 66.5) to (-20.0, 70.0)



Temperature
24 May 1987
(-18.0, 66.5) to (-20.0, 70.0)



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

ADA191961

| REPORT DOCUMENTATION PAGE | | | | | | | | | | | | | | | | |
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